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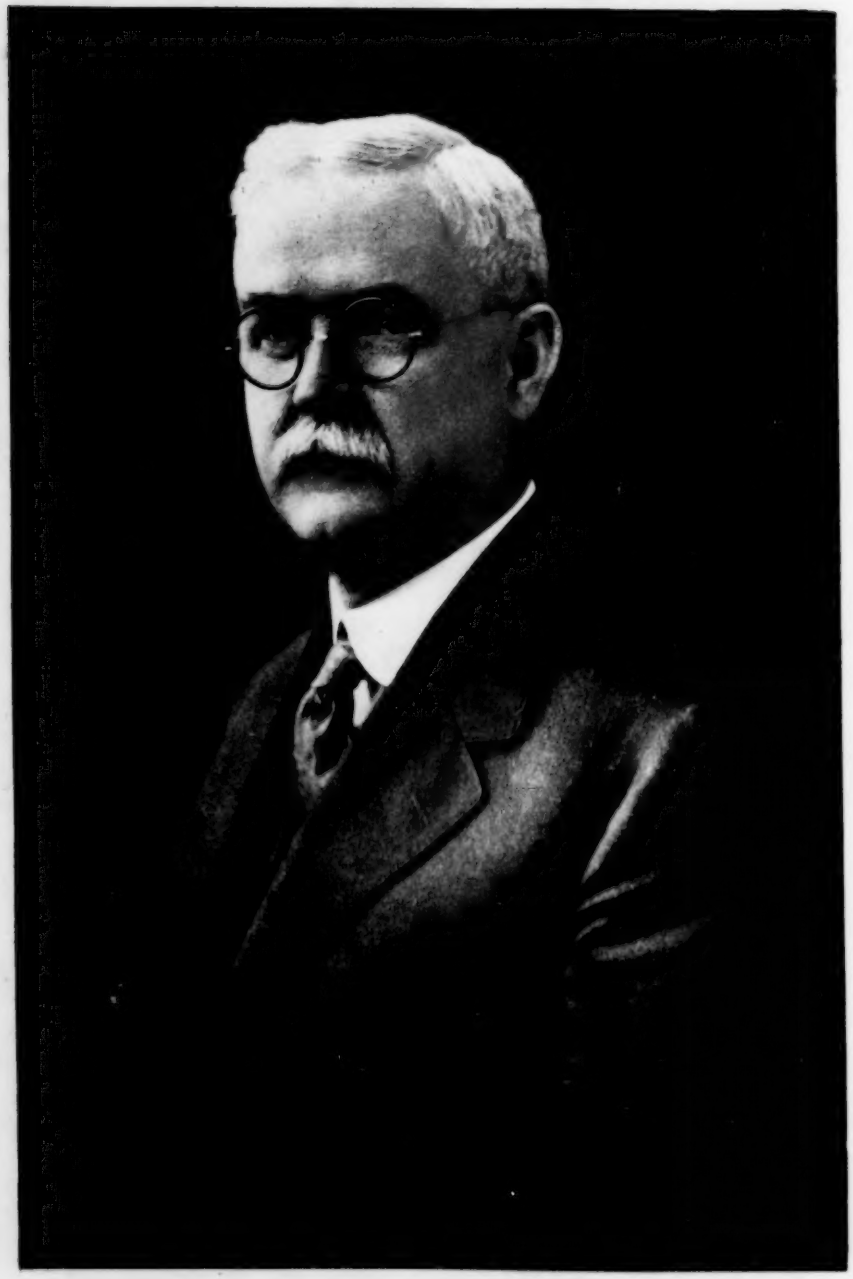

John S. Shearer.

THE AMERICAN JOURNAL OF ROENTGENOLOGY

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GRADUATE INSTRUCTION IN ROENTGENOLOGY*

BY J. S. SHEARER, PH. D.

Cornell University

ITHACA, NEW YORK

DURING a relatively short period roentgenology has established for itself a definite field of usefulness as an aid to the physician and surgeon. Like many other methods, it has solved problems where no one would have predicted success, and disappointed its votaries in fields where great expectations were at first entertained.

In common with most innovations in medicine, it has been compelled repeatedly to demonstrate its value, and struggle for adequate recognition, often retarded more by the extravagant claims of strenuous advocates than by the opposition of bitter enemies. Its development has been aided but little by the constituted machinery for medical education, or by the influence of great leaders in related fields, however clearly the latter now recognize its present or potential value.

Deeply as we may be interested in this development, and no matter how enthusiastic we may be as to its future, we should not forget that roentgenology is not an end in itself; neither can it reach its greatest value so long as it is not correlated with and adjusted to other methods of diagnosis and treatment.

For the purpose of discussion we may endeavor to define the term roentgenologist, and in part, at least, enumerate the mental qualifications he should possess. We might agree that a roentgenologist is a medical man who is skilled in the use of roentgen-ray methods for the diagnosis or treatment of disease. It is true that occasionally men who were not medical graduates have, in the past, become fully entitled to this designation; but they have acquired by practice, reading, and association what in the main the medical schools endeavor to teach, and in the future it may be expected that only medical men can properly qualify.

Assuming that the future roentgenologist is to be a medical graduate, and anticipating the introduction of the subject as an integral part of the courses in anatomy, physiology and pathology, let us consider what additional training is required and how it is to be obtained. In this connection we must not expect too much from undergraduate instruction solely through further additions; at least, not until some things are subtracted from the curriculum. The undergraduate curriculum is already overloaded, and almost invariably the specialist has a persistent habit of assuming that the student can devote an undue proportion of time to his specialty.

We are here concerned with the information or training, over and above that presumably acquired as an undergraduate, that is needed as a proper basis for the self-education that can only result from responsible work. Without the latter, no amount of instruction, however good, can provide a well-balanced roentgenologist.

First, there may be mentioned a minimum amount of technical knowledge,

* Read at the Midwinter Meeting of THE AMERICAN ROENTGEN RAY SOCIETY, Atlantic City, N. J., January 26–28, 1922.

covering only basic physical principles, the nature of the apparatus, the dangers involved and how to avoid them. The object is not to develop technical physicists or engineers, but to give a rational basis for instruction in the *use* of the roentgen-ray apparatus. I know there are some who hold themselves as absolved of all necessity for technical knowledge, who regard all such matters as beneath their intellectual level, and desire simply to appear as gifted interpreters of what may or may not be shown on the negatives; but I believe they are a minority.

Surely a well-trained roentgenologist should know his tools better than do those in his employ; otherwise he cannot secure the desired results, and is too often at the mercy of the technician.

A fundamental basic knowledge of the underlying principles, apparatus and measurements will tend to develop good sense and judgment in the purchase, arrangement and use of equipment. It should also tend toward emancipation from the dictation of agents, technicians and ill-informed people of all sorts whose influence is so unfortunate.

Do not imagine that I advocate long and arduous study of physics or engineering. The essential physics can be mastered in a few weeks in a well-organized laboratory under competent instruction. This should be given by men well grounded in physics who have acquired an interest in medical problems, and who can teach the subject without thinking the doctor should be a professional physicist.

The course should be given where there is a laboratory properly equipped, and a teacher of the right spirit and qualifications. There is need of only a few such laboratories, and those in charge should not be physicians, but physicists whose interest is aroused to the importance of this work, and who, moreover, are willing to acquire a knowledge of the mode of application of roentgenography in medical practice. Transplanting a physicist into a roentgen-ray laboratory will not lead to immediate results, and is quite as ridiculous as to put a physician in charge of a technical laboratory. All borderline subjects require cooperation to develop the best courses of instruction.

After such a course in the technical elements, there should be provided courses for the study of roentgenographic and fluoroscopic shadows of normal individuals of various ages. Only *good* negatives should be used in this work in order to impress on the beginner the type of negative best suited to diagnosis.

Following this, a study of negatives showing definite lesions should be made, and also a thorough review of the roentgenological aspects of gross pathology. Disputed and uncertain points should be avoided, and every effort made to correlate the *x*-ray evidence with that acquired by other methods.

Throughout all the work emphasis should be laid on the position of tube, plate and subject as related to the distribution of shadows observed. A reasonable amount of the history of the subject may well be included, but the discussion of obsolete apparatus and methods should be avoided as worse than useless, and confusing to the inexperienced.

Beyond this, instruction should proceed by actual practice both in the examination of patients and the interpretation of results under careful supervision of experienced and responsible roentgenologists. There is no substitute nor equivalent for this part of the training.

During the latter part of the course a fair portion of the student's time should be spent in studying the results of clinical examinations and in following to operation cases that have been diagnosed. He may hear the deductions of the roentgenologist fairly or unfairly criticised, but either will be an aid to him and he will learn what is of value to the surgeon and how it should be expressed. Such instruction should be given in hospitals that are under educational control.

We should never lose sight of the fundamental difference between roentgenology and most other laboratory methods. Excreta, blood and specimens are studied removed from the patient. But *x*-ray work is done on the living organism, and the element of responsibility for proper care and treatment of the individual is ever on the roentgenologist.

Assuming some such outline as a desir-

able solution of the problem, the next question is, how are we going to obtain it and where? Unfortunately the methods prevailing in the past are of less assistance than one might expect.

To summarize: We may hope that in some way the undergraduate may acquire a general knowledge of normal roentgen-ray anatomy, a clear idea of the diseases in which roentgenization is likely to be of diagnostic or therapeutic aid, and some familiarity with negatives showing indisputable proof of pathology; but all this without wasting time in the effort to make roentgenologists of inexperienced medical students.

The graduate intending to specialize in the use of this method should be provided with an opportunity to secure:

1. A knowledge of apparatus sufficient to enable him to judge of its necessity and worth.
2. Such a knowledge of dark-room work as will prevent domination by a photographer or technician.
3. A clear-cut knowledge of other methods of diagnosis in the lesions within his field.
4. As much gross pathology as can be secured.
5. Enough familiarity with operative surgery to enable him to know what information the surgeon needs, and the proper mode of expression.
6. Some familiarity with the main features of the historical development of his specialty.
7. Ability to judge of the relative importance of indications.
8. Such familiarity with the physical laws underlying the subject as will protect him from publishing irrational papers or accepting them from others.

How have the present generation of roentgenologists acquired their special knowledge? Reports in journals and at meetings have been available to some. In the majority of cases instruction has been unsystematic and uncoordinated. Often a student in a hospital course has had no responsibility and no check on his supposed proficiency. Mere observation will never fit men properly for work in roentgenology or any other specialty.

Most of the attempts to instruct, not only on the technical side, but on the clinical as well, have been made by salesmen of x-ray or photographic apparatus. Curiously, this encroachment in the field of medicine in combination with commercial propaganda has not only not been resented by the profession, but in general its statements have been taken as final authority.

I cannot refrain from quoting from an address by Osler in which we have only to read roentgenology instead of pharmacy to render it applicable to the present case:

"It may keep the practitioner out of the clutches of the arch enemy of his professional independence—the pernicious literature of our camp-followers, a literature increasing in bulk, in meretricious attractiveness, and in impudent audacity. To modern pharmacy we owe much, and to pharmaceutical methods we shall owe much more in the future, but the profession has no more insidious foe than the large borderland pharmaceutical houses. No longer an honoured messmate, pharmacy in this form threatens to become a huge parasite, eating the vitals of the body medical. We all know only too well the bastard literature which floods the mail, every page of which illustrates the truth of the axiom, the greater the ignorance, the greater the dogmatism. Much of it is advertisements of nostrums foisted on the profession by men who trade on the innocent credulity of the regular physician, quite as much as any quack preys on the gullible public. Even the most respectable houses are not free from this sin of arrogance and of ignorant dogmatism in their literature. A still more dangerous enemy to the mental virility of the general practitioner, is the "drummer" of the drug house. While many of them are good, sensible fellows, there are others, voluble as Cassio, impudent as Autolycus, and senseless as Caliban, who will tell you glibly of the virtues of bolism, and are ready to express the most emphatic opinions on questions about which the greatest masters of our art are doubtful. No class of men with which we have to deal illustrates more fully that greatest of ignorance—the ignorance which is the conceit that a man knows what he does not

know; but the enthralment of the practitioner by the manufacturing chemist and the revival of the pseudoscientific polypharmacy are too large questions to be dealt with at the end of an address."

One only needs to note the condition of many laboratories, crowded with expensive, complicated, even dangerous apparatus, to realize the extent to which commercialism and the immorality of salesmanship has invaded this field. Every conceivable means of complicating equipment has been used and under the guise of selling service the whole has been paid for either by the sick or by endowments for their care. But all this is of minor importance compared with the so-called instruction on the clinical side or in therapy so brazenly offered and, alas, so eagerly received. The law may forbid a layman to practice medicine, but there is no bar to his undertaking to tell the doctor how dangerous agents should be used, or what is the dosage to be given. It is not at all to the credit of the medical profession that they tolerate, much less court this abominable state of affairs. Both the profession, and those responsible for medical education owe it to themselves and to the public to find a remedy.

I am not at all unmindful of the efforts of manufacturers to assist in the development of appliances needed in this work. I take pleasure in the public acknowledgment of aid from several of them; but they surely should recognize that the salesman whose earnings depend on volume of sales, who is neither physician, engineer nor scientist is not to be entrusted with the education of those responsible for human life. Frankly I do not believe it is possible, in the long run, for a manufacturer or commercial organization, to disseminate accurate and reliable information, without subtle evasions and half-truths, consciously or unconsciously aimed to increase financial returns. Do not delude yourselves that you are getting something without cost. "Free service" is a most expensive luxury. It must be charged to overhead or selling expense and someone foots the bill. The amount paid in this way would more than support proper instruction and provide for research.

Another source of danger in instruction is the aggressive technician, especially when organized to secure aggrandizement of class. He talks glibly of things up-to-date, no matter how untried or ridiculous. He also by, training is neither physician, scientist nor engineer, but he insidiously assumes the rôle of all three. One of his strong points is in convincing the hospital superintendent that medical roentgenologists are not needed. For lo, he can make pictures galore and he always flatters the uninformed among the physicians by a seeming deference. Like system, he is a useful servant when kept within bounds, but a dangerous master and a most horrible educational example. One needs only to read some of the opinions expressed in certain journals to realize how dangerous he may become.

The proposition to license technicians is essentially bad. A state license is a dangerous tool in the hands of a small class, and gives no real guarantee of fitness. The only remedy effective against such conditions is in provision of such adequate means of instruction as will replace those of an objectionable character. So long as the constituted agencies for medical education fail to provide instruction in roentgenology, just so long will even the earnest and well-trained young physician be compelled to seek what may be found, and thus perpetuate the system.

From what sources are we to expect the proper education? The main agencies must be medical colleges, hospitals, roentgenologists and possibly a special institute.

Some, at least, of our medical colleges should provide for instruction in the physics of roentgenology as applied to medicine, and for well-balanced courses in clinical roentgenology, both diagnostic and therapeutic. Hospitals associated with medical schools should provide for the use of their material for instruction by members of the staff. A hospital giving instruction to students with no college affiliations is quite prone to look upon the student as a cheap assistant who is welcome to what he can pick up if he does not interfere with routine, or if he does

more than enough general work to make himself profitable. Only where the intent to instruct is a dominant feature, will there be well-developed courses. In such courses, those who intend to practice roentgenology must be required to carry through complete examinations, subject to check and criticism. No amount of reading, listening to lectures, or observation of the work of others will suffice. It is not that they should later do all the detail work, but that unless they know well how to do it they will be unable to get results from employees or assistants.

Perhaps the most important source from which we ought to receive both inspiration and aid is the medical profession, and especially the roentgenologists themselves. Unless they realize the defects of present methods and are brought to a conception of needs and possibilities, there is but slight chance of interesting schools and hospitals. Everyone familiar with good work with *x*-rays and radium should become a center of educational influence. Not of propaganda for more elaborate electro-mechanical equipment or for spreading extravagant claims, but an exponent by word and deed of the highest ideals in training and practice. You, as representatives of your specialty, cannot expect the world to place a higher valuation thereon than you yourselves are doing. You have no higher duty and possess no greater privilege than to provide such opportunities and inspiration to your younger associates as will bring results far superior to those you have been able to achieve. While only a few can actively engage in teaching, there is none among you who can not aid in urging provision for instruction and research. Whenever opportunity offers, aid and encouragement should be extended to beginners. Some among you may be able to permit an occasional earnest and qualified worker to spend sufficient time with you to carry away enough of your experience to provide a nucleus for real advancement. The old method of "reading" with the experienced physician had some advantages lost to great educational machines.

The sole legitimate excuse for meetings of societies and the publication of journals is their educational value. For this reason you have a responsibility for the future in insisting that only articles and papers of real value as judged by the highest standards of the time are allowed on your programs or in your journals. These should be used neither for self-advertisement nor commercial propaganda.

Another means of education is the publication of atlases of normals of various ages as well as those of various well-defined lesions. These should be transparencies to correspond in light and shade to what the roentgenologist actually sees. The price should be within reach of young practitioners. It would seem some man of wealth in this country could be found who would make this possible.

Finally, there should be provision for a combined teaching and research institution or institute of roentgenology, where the problems of the future may be attacked and where those who come can receive the inspiration that is only to be found where research is carried on. The relation of roentgenography to medicine is not a finished book: the introduction only has been written. He who regards our present views as final or our practice perfect, is intellectually dead even though still counted among the living.

Such institutions have been established or very soon will be, in several European centers.

In his presidential address to the British Roentgen Society, Knox said: "The Mackenzie Davidson Memorial Fund has been started with the object of providing an Institute of Radiology. It has been customary to appeal for funds in the hope that a philanthropic millionaire might be induced to provide and endow such an institution. To my mind it would be a much more satisfactory method if each and all of us became a collecting center for the fund. Let us take an example from Russia. A medical correspondent writing in *The Lancet* recently referred to the progress of medicine in Russia during recent times. Two new Institutes have been inaugurated at Petrograd; one of these is an Institute of Roentgenology and Radiology. It was instituted in a building of recent construction. In the courtyard of the

Institute is a tablet commemorating the discovery of *x*-rays by Professor Roentgen, and inscribed beneath his name are the names of physicists who have contributed to the subject.

"In the midst of the upheaval—the like of which the world has never seen—Bolshevik Russia can erect an Institute of Radiology. Are we in Britain going to be out-done in the matter of scientific research by Russia? We should lead in the subjects embraced under the general head of Radiology. It is with pride we regard the great advances in physics which have had their origin in this country.

"The subject is in its infancy; the discoveries of the past may well be eclipsed by those of the future. Let us be prepared to do our share in these advances. The only efficient way is by the organization and endowment of research."

When we in the United States compare the extent and wealth of this country with that of others, when we consider the enormous expenditures made here for elaborate equipment, when we realize that we are the largest producers of radium and of *x*-ray tubes in the world, we may well consider for a moment whether we have given our share toward providing for future developments. Why not have an Institute which would command the respect of the world and put us in the front rank in that greatest of human activities, the discovery of the truths of nature and their proper application to human needs?

Many of those who did pioneer work in this field have passed on, alas, often scarred and maimed even as those who fought other battles where destruction of life, not its preservation, was the aim. They suffered on account of lack of knowledge, but they made it possible for those who followed to walk safely. The world should somehow build an appropriate monument to them. What would be more fitting than an institution where the things they saw as visions might be realized and where might be continued the glorious tasks for which they made such noble sacrifices?

In the erection of such an institute we would show future generations that we appreciated such men, and in carving their names on a memorial tablet in an institute devoted to such work we would only in a small degree render honor to whom honor is due.

GRADUATE INSTRUCTION IN ROENTGENOLOGY

BY G. W. HOLMES, M.D.

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BOSTON, MASSACHUSETTS

INTRODUCTION

I SHALL not attempt, in this brief discussion, to go into the history of this work in connection with roentgenology, or to present any data obtained from other teaching clinics, but will outline the courses which we are giving at the Massachusetts General Hospital in connection with the graduate teaching of the Harvard Medical School, and present some of the observations which I have made.

1. THE NEED OF POST-GRADUATE TEACHING

In order to establish a satisfactory course of instruction, one must first consider the need for post-graduate instruction in his vicinity, and second, the type of students likely to apply for instruction.

It is only within the last few years that roentgenology has been taught as a required subject in our larger medical schools; therefore, the medical profession as a whole has no definite knowledge as to its use or method of application either in diagnosis or treatment. There is a real need that these men who have been in practice for some time be given courses in roentgenology similar to those given under-graduate students, so that they may become familiar with its use. They should be able to decide in a given case whether an *x*-ray examination is necessary or not, and also be able to instruct the patient to some extent as to the nature of the examination and the time consumed in doing it.

Every physician should also have sufficient knowledge of radiology to enable him to judge the work of the specialists in this field, so that he may select competent men to whom to refer his patients. At the present time, if the quality of the plates shown is satisfactory, the consultant is usually satisfied. He is unable to go beyond this in a test of skill.

There are also men in the smaller towns engaged in general practice, who are doing considerable *x*-ray work. As a rule, these men have received most of their instruction from the dealer from whom they purchased their apparatus. Frequently, they are quite ignorant of the extent of the field in which they are working,—of its literature and of the standard of work which they should maintain.

In the smaller towns unable to support a specialist, it is necessary that someone be prepared, to do at least the simpler *x*-ray examinations; and I believe these men should be encouraged to do the best work possible.

There is a tendency, at the present time, for men engaged in the specialties, particularly those specialists who deal with a single organ of the body, to do all the work connected with their field. If these men are to do their own *x*-ray work, it is necessary to give them opportunity for special training in it.

In the larger clinics, the internist is gradually becoming a very important factor in the final diagnosis. After all the laboratory and clinical data have been collected, it usually falls to him to analyze it and decide upon the diagnosis and treatment. These men, as a rule, have had less training in roentgenology than in any of the other specialties with which they come in contact. In order that they may judge the value of the roentgen-ray findings in connection with other clinical and laboratory examinations, they should have some actual training and experience in this work.

If roentgenology is to continue and maintain its position among the other medical specialties, it is necessary that young men be trained particularly for it. These men should be selected from the student body, preferably those who show a special trend and adaptability, and who have had preparatory work in physics.

2. THE TYPE OF STUDENTS APPLYING FOR INSTRUCTION

That this opinion is held generally by the profession at large is shown by the type of students applying for instruction, a large number of whom are general practitioners who are not recent graduates, but who wish to obtain a general knowledge of the use of the *x*-ray, particularly in diagnosis.

Perhaps the second largest group consists of men engaged in a specialty, who wish to obtain a more extensive knowledge of radiology, so that they may use better judgment in selecting cases for examination and in estimating the relative value of the roentgen-ray findings. Many of this group, however, intend to do their own *x*-ray work in connection with their specialty.

The number of young men who wish to prepare themselves for roentgenology as a specialty is increasing gradually, and many of them are of the best type.

3. THE CHARACTER OF INSTRUCTION GIVEN

It is obvious from a study of the need for instruction, and the type of man seeking it, that no one course would be wholly satisfactory.

Short courses, consisting largely of clinical work, supplemented by lectures and conferences, are required for those men who do not intend to practice roentgenology as a specialty, but who wish a better understanding of the subject for use in their general work. This course, supplemented by well-directed reading, will be of value also to the practitioner in the small town who is doing some *x*-ray work. Time and expense with him are factors to be considered; and I believe that it is better for him to know what good work is, and to have a general knowledge of the literature on the subject than to remain purely a technician. A course of this kind of one month's duration, which we have been giving for the past five years, has, at least, been well patronized. Students are in the laboratory from nine a.m. to five p.m. The work is so arranged that they can observe the actual running of the clinic. From nine to ten o'clock in the morning, they attend the therapeutical clinic; from ten to eleven, plate interpretation. These are not selected plates, but the routine morning's work. Interpretations are dictated, and discussion of the cases is encouraged. From eleven to twelve o'clock, they observe fluoroscopy of the chest, and from twelve to one o'clock, plate-taking; from one to two p.m. is the lunch hour. From two to four o'clock in the afternoon, they observe gastrointestinal fluoroscopy. The students are not given actual work, but they see all cases examined, and there is opportunity to study the cases and to follow many to operation. From four to five p.m., the day's work is gone over and discussed in conference, or a talk is given, using specially selected plates.

For the specialist who wishes to do his own *x*-ray work, our facilities for teaching are not as satisfactory as desired. These courses should be at least of six months' duration. Observation in the special clinic, combined with reading and conferences, should be followed by actual clinical work. It has been our practice, after these men have had their preliminary instruction, to have them appointed as graduate assistants, and to allow them to be responsible, under a director, for the special clinic in which they are interested. Thus far, this has been done in therapeutical work, gastrointestinal work, and eye, ear, nose and throat work.

Probably the most important work in this field, at least to us roentgenologists, is the preparation of young men seeking to enter the specialty. In my opinion, this cannot be done satisfactorily outside of a large hospital clinic, preferably in a medical center. These men should be given special courses in physics, pathology and anatomy, and should have opportunity to obtain actual experience in the examination and study of cases. It is desirable that these cases be examined also by all other laboratory and clinical methods. They should become familiar also with the roentgen-ray literature. We have found that the investigative work going on in a teaching hospital is a stimulus to such men to do this, and if they can be given some problem for investigation with the preparation of a thesis, another incentive to study is brought about. A course of this kind should be at least of one year's duration.

The first part of the day, usually the forenoon, for the first three months, is given up to work in the pathological and anatomical laboratories at the Medical School, and in the physical laboratories at the college. During this time, they are assigned certain groups of cases, usually those requiring the taking and developing of plates, for study in the hospital clinic. Later, they are given other clinics, such as the chest, therapy and gastrointestinal, under the supervision of a director, their position being much like that of a house officer to the visiting man in a medical clinic. As early as possible, they are assigned some special subject for study; and the last few months of their routine work is made as light as possible, so that they may have opportunity to complete investigations and prepare their theses.

I realize that it is impossible properly to train a roentgenologist in one year's time. On the other hand, very few men, after their college and medical courses with a year or more of hospital training, can afford more than this period of time without a salary. As far as possible, men graduating from such courses should be placed in positions as paid assistants to older men, from which positions (after a period of five years) they should be prepared to take charge of a large laboratory or teaching clinic.

SUMMARY

There is a widespread need of post-graduate instruction in roentgenology.

That the general medical profession realizes the necessity of this instruction is shown by the number and class of men seeking instruction.

The radiologists connected with teaching hospitals should be prepared to give this instruction.

Courses should be adapted to the needs of the students.

MEASUREMENT OF ROENTGEN RADIATION BY MEANS OF AN IONIZATION CHAMBER AND GALVANOMETER

BY WILLIAM DUANE

Professor of Biophysics, Harvard University

CAMBRIDGE, MASSACHUSETTS

The method of measuring the quantity and quality of roentgen radiation described in this paper differs only in minor details from that presented by the writer to the American Roentgen Ray Society in 1914. (See also the reports of the Cancer Commission of Harvard University, 1913–1915.) The improvements in the method that have been made during the last eight years are due, largely, to the fact that more reliable and more sensitive galvanometers can now be purchased, and to the fact that modern *x*-ray plants produce more intense beams of rays. These facts have enabled me to reduce the size of the ionization chamber, and thus make it more convenient to manipulate. Whereas the volume of the ionization chamber in the instruments I employed eight years ago amounted to 200 c.c. or so, that of the instrument here described need not exceed 10 c.c.

The ionization chamber consists of a series of aluminum sheets, about 5 cm. long and 2 cm. broad, held parallel to each other at distances apart of about 2 mm. by hard rubber frames. Alternate sheets of aluminum are metallically connected together, thus forming two interlocking sets of sheets electrically insulated from each other. The sets of sheets thus form a small electrical condenser with layers of air between them. The condenser is joined in a simple electric circuit with a battery and a very sensitive galvanometer. The galvanometer should be so sensitive that less than 10^{-10} ampère produces a deflection of one division on

its scale. The wires connecting the ionization chamber with the battery and galvanometer must be highly insulated, and they should pass through a flexible metallic sheath. The flexibility of this circuit allows the ionization chamber to be placed in any desired position in the *x*-ray beam.

If the ionization chamber lies in a beam of *x*-rays, the rays ionize the air between the sets of plates, a current flows through the circuit and the deflection of the galvanometer measures its strength. The deflection of the galvanometer may be taken as a measure of the intensity of the *x*-ray beam at the place where the ionization chamber lies.

In order that the readings made with different instruments and by different observers, etc., may be compared with each other, it is necessary for each instrument to be standardized. The standardization consists of two parts: (1) the calibration of the galvanometer; (2) the calibration of the ionization chamber.

Galvanometers as sensitive as those required for measurements of this kind do not all give the same readings for the same current. Further, one and the same instrument may show somewhat different deflections at different times for the same current. In order to determine the magnitude of the deflection produced by a given current at any particular time, I use a small box containing a Weston Standard cell and electrical resistances. These circuits are joined to the galvanometer in such a way that on pressing a key, a current passes through it from the standard cell. The values of the resistances in the box are so chosen that a given current passes through the galvanometer on closing the key. If the standard cell and resistances have been well constructed, the current obtained from the box remains always the same to within an accuracy amply sufficient for *x*-ray measurements.

If the electromotive force of the battery in series with the ionization chamber is not large enough, the current through the ionization chamber will depend upon its value; for the force pulling the ions in the gas across to the aluminum plates may not be sufficient to carry across all of the ions produced by the *x*-rays. In other words, the ionization current is not what is called saturated for small electromotive forces. If, however, the electromotive force has a high value, it becomes sufficient to drive practically all of the ions produced by the *x*-rays across to the aluminum plates. Under these conditions the ionization current is said to be saturated, and its value no longer depends upon the electromotive force of the battery. In calibrating the ionization chamber, the first thing to do is to determine how large the electromotive force of the battery must be in order to produce saturation. This can be done by altering the number of cells in the battery, and by noting the deflections produced in the galvanometer. If the galvanometer deflection no longer increases on increasing the number of cells in the battery, the saturation electromotive force has been reached. As a matter of fact, a few volts suffice to saturate the ionization current in an ionization chamber such as that described above, when it lies in a beam of *x*-rays produced under ordinary working conditions.

In order that the measurements made with one ionization chamber may be compared with those with other ionization chambers it is necessary to adopt some unit of *x*-ray intensity. The unit I was using in 1914 may be called the electrostatic unit. It may be defined as the intensity of roentgen-radiation that produces the electrostatic unit of ionization current per cubic centimeter of air under normal conditions of pressure and temperature.

In order that this unit may be available for accurate measurements, care must be taken that no secondary radiation from the electrodes of the ionization chamber passes through the cubic centimeter of air, and that the total ionization from all the secondary corpuscular radiation produced from the cubic centimeter of air is measured. The writer called attention, as early as 1905, to the fact that errors might be made in ionization measurements, if account were not taken of the absorption of corpuscular radiation by the walls of an ionization chamber. (See *Journal de Physique*, 1905, IV, 605.)

In the ionization chamber described above, the required conditions are not fulfilled. It becomes necessary, therefore,

to compare the current in this ionization chamber with the current in a standard ionization chamber of large dimensions and so constructed that the rays passing through it do not strike any solid substance inside it. The standard ionization chambers that I was using in 1914 had volumes ranging from 500 c.c. to 2,000 c.c. They were constructed in such a way that the *x*-rays passed through holes in a sheet of lead 1 cm. thick, and so that the rays coming through these holes always passed between, but did not strike any of the electrodes inside the chamber. Probably the most satisfactory arrangement of electrodes is that adopted by Lord Kelvin in his standard Guard Ring electrostatic capacity. Friedrich describes an accurate ionization chamber based on this principle.

By comparing the ionization current in the aluminum sheet condenser described above, with those due to the same *x*-rays in a standard ionization chamber, it is possible to calibrate the aluminum ionization chamber, and thus determine the intensity of the *x*-ray beam in terms of the electrostatic unit of intensity.

When properly calibrated, the deflection of the galvanometer gives us the *intensity* of an *x*-ray beam. In order to measure the average or "effective" wave-length of the rays in a beam, I use the ionization chamber to determine the fraction of the roentgen-radiation passing through ½ mm. or 1 mm. of copper and then estimate the effective wave-length by means of the curve given on page 170 of the AMERICAN JOURNAL OF ROENTGENOLOGY, March, 1922. As an alternative measurement of an effective wave-length I use the ionization chamber to determine the thickness of aluminum that is equal in absorbing power to 1 mm. of copper, as described in Section 6 of the above-mentioned article.

ROENTGEN-RAY TREATMENT OF CHRONICALLY INFECTED TONSILS AND ADENOIDS*

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PROBLEM

THE roentgen-ray treatment of infected and hypertrophied tonsils and adenoids was undertaken with a view to determine (1) whether the same clinical results could be accomplished as in tonsillectomy and adenoidectomy, and (2) whether there was a persistence of the carrier state. Twenty-one cases were treated. As the records are incomplete in 7 cases, discussion is limited to the results in 14 cases. All these cases were seen in the Out-patient Department of the Johns Hopkins Hospital, and all of them were suffering from infected tonsils or adenoids.

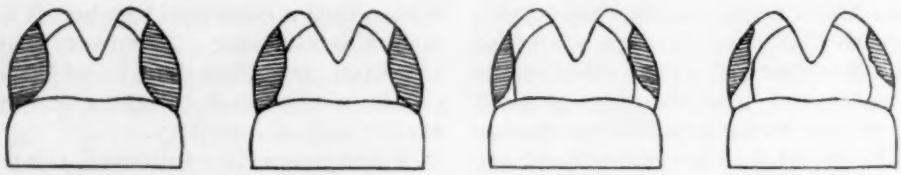
PROCEDURE

With the beginning of treatment, swabs were taken from the surfaces of both tonsils and the nasopharynx, and cultures made according to the method of Bloomfield. The distance between the two tonsils was measured and recorded on the forms shown in the diagrams. The successive measurements were made by one person, Dr. J. W. Baylor, so that the source of error would be minimal. A series of four *x*-ray exposures was given, approximately two a week for two weeks. After a rest of several weeks a second series was given. Cultures and measurements were taken frequently. Our thanks are due to the efficient aid of a social worker, Miss Foley, who saw to it that the patients came back for their treatments.

CHRONIC TONSILLITIS—TEN CASES

Ten cases were children under twelve years of age, who were suffering with

* Read before the Midwinter Meeting of the Eastern Section of THE AMERICAN ROENTGEN RAY SOCIETY, Atlantic City, N. J., January 27, 1922.



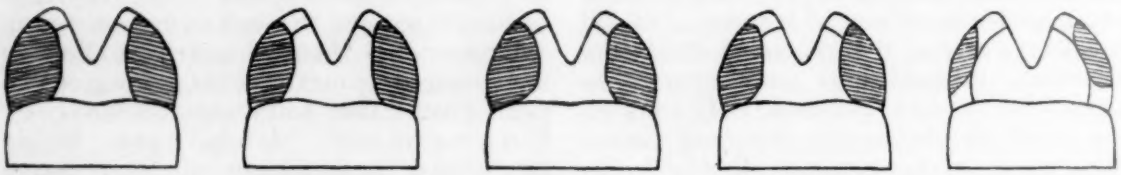
10–12–21
2 days after
1st series.

10–28–21
18 days after
1st series.

12–9–21
End of 2nd
series.

1–9–22
31 days after
2nd series.

FIG. 1. Distance between tonsils increased 6 mm. (W. R. C-M-9 yrs.)



9–24–21
Before treat-
ment.

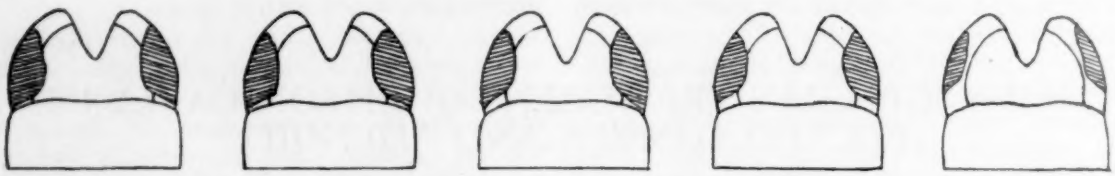
10–12–21
8 days after
1st series.

10–28–21
24 days after
1st series.

11–25–21
End of 2nd
series.

1–9–22
45 days after
2nd series.

FIG. 2. Distance between tonsils increased 11 mm. (C. S. C-M-9 yrs.)



9–24–21
Before treat-
ment.

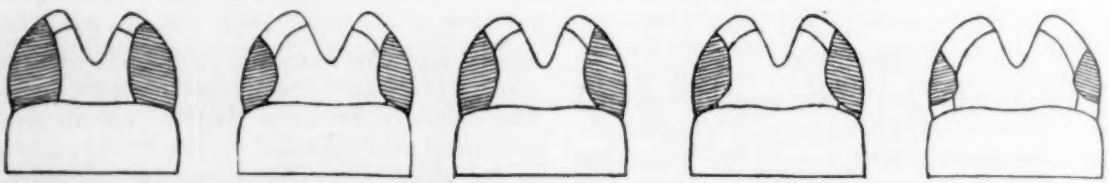
10–12–21
8 days after
1st series.

10–28–21
24 days after
1st series.

12–9–21
6 days after
2nd series.

1–9–22
37 days after
2nd series.

FIG. 3. Distance between tonsils increased 6 mm. (B. S. W-F-7 yrs.)



10–12–21
During 1st
series.

1–19–22
27 days after
2nd series.

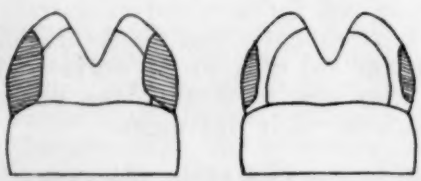
FIG. 4. Distance between tonsils increased 6 mm. (E. H. C-F-12 yrs.)

11–5–21
15 days after
1st series.

12–16–21
End of 2nd
series.

1–19–22
34 days after
2nd series.

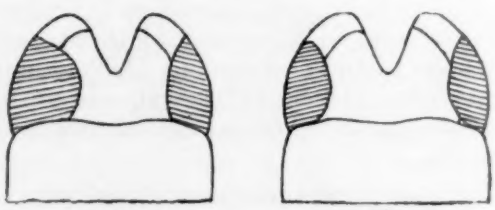
FIG. 5. Distance between tonsils increased 5 mm. (D. T. C-F-6 yrs.)



10–12–21
11 days after
1st series.

12–17–21
77 days after
1st series.

FIG. 6. Distance between tonsils increased 9 mm. (R. C. W-F-11 yrs.)



9–24–21
Before treat-
ment.

10–28–21
24 days after
1st series.

FIG. 7. Distance between tonsils increased 5 mm (E. W. C-M-9 yrs.)

chronic tonsillitis and hypertrophied adenoids. In each case a diagnosis was made on the basis of a history of frequent colds and sore throats with occasional attacks of acute tonsillitis, the presence of enlarged tonsils and adenoids, palpable glands at the angles of the jaw and the absence of any general constitutional disease. Five cases had one complete series of four exposures; 5 cases had two complete series of four exposures each. Anatomically the tonsils have appreciably shrunken in all but one case. The distance between the tonsils has increased as follows:

5 cases which had two complete series:

W. R.	6 mm.
C. S.	11 mm.
B. S.	6 mm.
E. H.	6 mm.
D. T.	5 mm.

5 cases which had one complete series:

R. C.	9 mm.
E. W.	5 mm.
D. N.	6 mm.
R. B.	No appreciable difference
P. K.	7 mm.

The general appearance of the cases which had two complete series was that they had shrunken to normal size, and no further treatment was necessary. While the distance between the tonsils in the cases which had had but one series increased as much as in those which had had two series, it was felt that all would need another series of treatments except the case R. C. This case had had a tonsillectomy four years previous. Reference to the charts will show that in those cases in which the largest number of observations have been made, the greatest shrinkage took place about one month after the second series.

RESULTS

In each of these 10 cases, the clinical symptoms for which they originally came to the hospital have disappeared. The cases have not been observed for a long enough time to determine whether this is the result of the tonic effect of the *x*-ray treatment, or whether it is due to lessened absorption from the foci of infection which have been shown to persist. At the last examination, the glands at the angle of the jaw, which were enlarged on admission, were still palpably enlarged. The bacteriological results were completed in 5 of the cases which had two complete series, and the 3 cases which are to follow, which also received two series. The bacteriological studies are confined to these 8 cases, and the results noted under the section on bacteriology.

TECHNIQUE OF TREATMENT

While we have not followed the treatment technique as advocated by Murphy and his associates, yet the same general principles have been adhered to.

Our treatments consist of 5 ma. of current filtered through 4.5 mm. of glass and ½ inch layer of orthopedic felt, employing 120,000 volts, approximately a 7 inch spark gap, and using a 25 cm. focal distance for a period of five minutes.

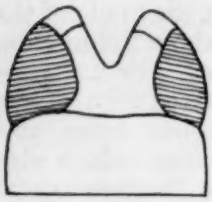
The exposures were given as follows: Mondays and Fridays for two weeks—which we termed one series of treatment. The patients were then allowed to rest for a period of three or four weeks before starting the second series of treatments. We followed this routine in our treatment of these 8 cases.

None of the patients have received more than two series—comprising in all eight treatments.

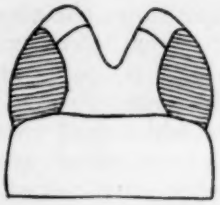
This, of course, is a larger *x*-ray dose than advocated by Murphy, Witherbee, Osgood and others, who recommended the sub-erythema dose, while our dosage has reached the reaction or mild erythema stage.

Whether the good or bad results in our series of cases were due to too much irradiation we hesitate to say; but surely it has not been the result of insufficient radiation.

The rays were directed in such a manner that the perpendicular beam passed below the lobe of the ear, under and just posterior to the angle of the jaw. The entire body, with this exception, was covered with a heavy piece of lead rubber sheeting, the parotid gland being doubly protected by a heavy piece of lead foil, one mm. thick. The exposed surface area measured approximately 8 × 9 cm.

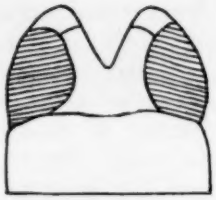


10–28–21
7 days after
1st series.

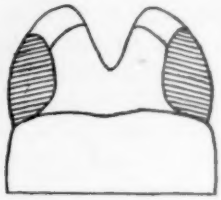


1–19–22
95 days after
1st series.

FIG. 8. Distance between tonsils increased 6 mm. (D. N. C-F-8 yrs.)

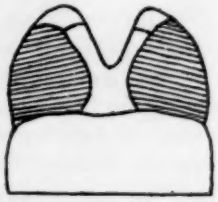


10–28–21
11 days after
1st series.

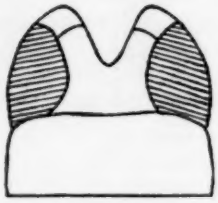


1–19–22
95 days after
1st series.

FIG. 9. No appreciable difference in distance between tonsils. (R. B. C-M-5 yrs.)

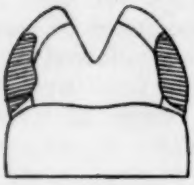


11–9–21
Before treatment.

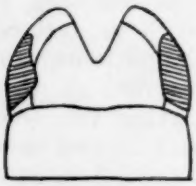


1–19–22
47 days after
1st series.

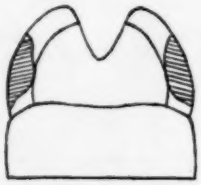
FIG. 10. Distance between tonsils increased 7 mm. (P. K. W-F-12 yrs.)



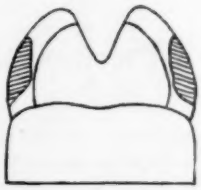
10–6–21
Before treatment.



10–28–21
4 days after
1st series.

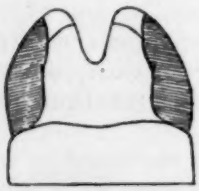


11–5–21
12 days after
1st series.

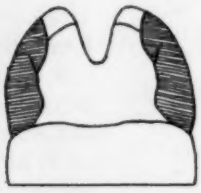


1–6–22
End of 2nd series.

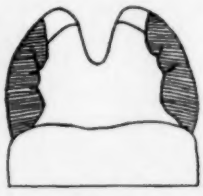
FIG. 11. Distance between tonsils increased 4 mm. (H. C. W-M-12 yrs.)



10–28–21
17 days after
1st series.

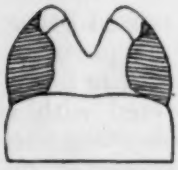


11–18–21
1 day after
2nd series.

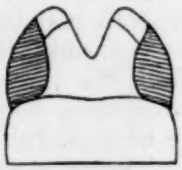


12–19–21
32 days after
2nd series.

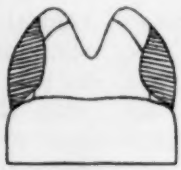
FIG. 12. No appreciable increase in distance between tonsils. (B. T. C-F-56 yrs.)



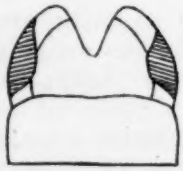
9–24–21
Before treatment.



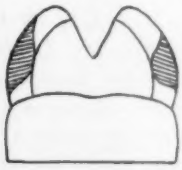
10–12–21
8 days after
1st series.



10–28–21
24 days after
1st series.



12–9–21
6 days after
2nd series.



1–9–22
37 days after
2nd series.

FIG. 13. Distance between tonsils increased 10 mm. (A. S. W-M-11 yrs.)

REACTIONS

Treatment. 1. Five cases had one series of treatments.

2. Five cases had two series of treatments.

3. Four cases had skin reactions after receiving one series.

4. One case had skin reactions after receiving two series.

5. In no case was there atrophy of the parotid glands.

The adult patients developed a very faint blush after the first series, which lasted about one week. In the men patients there was some epilation of the beard.

In the children a more definite blush or mild erythema developed after the first series, which lasted a trifle longer than in the adults, usually about ten days or two weeks.

All the erythemas cleared up in a few weeks, with no tanning or telangiectasis, the skin completely returning to normal.

X-ray plates of the jaws in every case showed no evidence of changes in the dental structures as a result of the *x*-ray treatments.

SYDENHAM'S CHOREA WITH CHRONIC TONSILLITIS—ONE CASE

This case, H. C., a boy of twelve years, developed chorea three years ago, following a severe attack of tonsillitis and joint pains. He has had more or less, choreiform movements ever since. This is usually worse in the spring of the year. Examination showed him to be suffering with chronic tonsillitis. He was given two complete series of treatments with the following results: Clinically the choreiform movements have improved since the treatment was begun. His mother states that she has not noticed any nervous twitchings since the treatment was begun, and he has had no colds nor sore throats. There has been a decrease in the size of the tonsils, so that the distance between them has increased 4 mm. The hemolytic streptococcus was present throughout the first course, but absent throughout the second course of treatment. No cultures have been made since the last *x*-ray treatment.

This case indicates one condition where roentgen-ray therapy would be extremely serviceable. In this condition it is especially desirable to relieve the patient from chronic focal infection in the nose and throat, and to prevent recurring colds and tonsillitis. Surgical operation in the acute or subacute stage of chorea may be a very dangerous procedure, for the operation may stir up an acute endocarditis, while roentgen-ray therapy would not do this.

CHRONIC INFECTIOUS ARTHRITIS WITH CHRONIC TONSILLITIS—ONE CASE

This case, B. T., a woman of fifty-six years, has had polyarthritis for fifteen years, and has had frequent sore throats since childhood. Examination showed large adherent irregular tonsils and a moderate-sized mass of adenoid tissue, as seen by the nasopharyngoscope. The patient received two complete series of *x*-ray treatments, with the result that clinically the general symptoms and throat condition were very much improved. However, there was no measurable decrease in the size of the tonsils, and the hemolytic streptococcus was still present four weeks after the second series.

It will require many cases to determine the effectiveness of roentgenotherapy in removing chronic focal infection in tonsils that are giving rise to a general constitutional malady, such as arthritis, glomerular nephritis, etc. In view of the results as brought out in the section on bacteriology it would amount to malpractice to resort to *x*-ray treatment alone when surgical removal might save the patient.

CHRONIC SUPPURATIVE OTITIS MEDIA WITH CHRONIC TONSILLITIS—ONE CASE

A. S., a boy of eleven years, gives a history of repeated sore throats and attacks of tonsillitis and a discharging ear, since infancy. Examination showed greatly enlarged tonsils, no adenoid tissue, palpable glands at the angle of the jaws and purulent discharge from the right ear. He was given two complete series of *x*-ray treatments, and at the same time his ear was treated with alcohol and hydrogen peroxide. Clinically he has been free from colds and attacks of tonsilitis. The ear has

ceased to discharge. The tonsils have decreased markedly in size—the distance between them has increased 10 mm. The glands at the angle of the jaws remain palpable. The hemolytic streptococcus was found only on two occasions at an interval of one month, and was still present five weeks after the last treatment.

This case is interesting, in that it offers a possible way to clear up these chronic cases of suppurative otitis media. Evidently roentgenotherapy causes a shrinkage of the infiltrated mucous membrane lining the Eustachian tube and middle ear. However, no definite statement should be made on this until pathological sections have been studied.

ACUTE CATARRHAL OTITIS MEDIA—ONE CASE

This case was a college student who had been deaf in his left ear for one month following a very severe cold. Examination showed small tonsils, glands not enlarged, but a large inflamed mass of adenoid tissue compressing the right Eustachian orifice and, to a less extent, the left one. He was given one series of four treatments, but at the same time his nasopharynx was treated with silver nitrate. He had a marked reaction with considerable swelling of both sides of the neck and some sore throat after the first treatment. He had no reaction after the second treatment, and a very mild reaction after the third. A roentgen-ray dermatitis developed over the front and sides of the neck about one week after the fourth treatment. Examination at this time showed that there was no reduction in the size of the lymphoid tissue in the nasopharynx. Twenty-seven days after the fourth treatment, the patient had a tonsillectomy and adenoidectomy. A pathological section of one of the tonsils showed that apparently the germinal centers were not affected by the *x*-rays, but that the lymphoid cells between the germinal centers disappeared, and their place was taken by fibroblasts.

INCOMPLETED CASES

This series included 6 cases of chronic tonsillitis and one case of chronic catarrhal otitis media of two years' duration. This last case stopped treatment after two exposures, due to the severe reaction—swelling of the salivary glands and sore throat—which followed each treatment. Two of the cases of tonsillitis showed great improvement, with the almost complete disappearance of all their symptoms. It has been impossible to keep in touch with the other 4 cases.

BACTERIOLOGY

In addition to observations on the clinical progress of the cases under discussion, it was considered of interest to note such changes as might occur in the bacterial flora of the throats. If it could be shown that retrogression in the size of the tonsils was accompanied by the subsidence of the carrier state in such of the subjects as might harbor pathogenic bacteria in their throats, the advantages resulting to the individual would be obvious. The rôle of foci of infection in the production of local and systemic derangement need not be discussed here—the subject has been thoroughly treated in a voluminous and readily accessible literature. It is well known that tonsillectomy may be followed by marked improvement in divers disorders of varying degree. The importance of prophylactic eradication of these foci, if it could be accomplished by the methods described above, need not be emphasized—it will become apparent without further reflection.

Doubtless because of the novelty of the irradiation method of treatment, there is very little literature dealing with the changes produced in the bacterial flora. Murphy[1] and his associates noted the disappearance within four weeks, of hemolytic organisms from 30 to 36 carriers. No record is adduced of subsequent study of the individuals. The suggestion is made that proper drainage of the crypts is responsible for the change. Osgood[2] advances the same conclusion. In his paper there is no citation of case reports or bacteriological studies.

TECHNIQUE

The material for culture was obtained by means of surface swabs, systematically passed over the desired areas, in the endeavor to obtain a heavy inoculation which

would be fairly representative of the actual flora present. For the first cultures, only the tonsils were swabbed. Later, for purposes of comparison, a swab from the pharynx was added. In every case, a separate culture was taken from each tonsil, and careful precautions were observed to prevent contamination of the swabs from surfaces other than those under consideration. The difficulties of the procedure with children of tender age will be appreciated.

For the study of the flora, 3 per cent rabbits' blood meat infusion agar, PH 7, 8–7.4, plates were used in every instance. It was found preferable to use media not more than forty-eight hours old. The first plate was rather heavily inoculated with the swab over about ⅓ of its surface. A heavy platinum wire, bent at a right angle, was used to obtain an even spread over the remaining surface of the medium, and was then transferred without flaming to a second plate, which was similarly inoculated over its entire extent. In this way, an even distribution of colonies was obtained over the second plate—occasionally even the first was suitable for study. The plates were incubated for eighteen hours, and then observed for the presence and relative numbers of colonies of the various bacteria under consideration. Identification of the organisms was accomplished by means of stained films, and subculture when necessary, in every instance. It soon became evident that the beta hemolytic streptococcus and the staphylococcus aureus were the organisms of choice for study—both on account of their well-known pathogenic potency, and because it was at once apparent that they were the only bacteria of such character to be present as more than transient visitors. Occasionally were found Friedlaender's bacillus, pneumococci, B. Coli, and rarely others—but never frequently enough to justify serious consideration in this paper. The influenza bacillus was of somewhat more frequent occurrence, but is not treated of here, in view of its somewhat uncertain potentialities. The ubiquitous non-hemolytic streptococci and chromogenic gram-negative cocci were omnipresent.

RESULTS

The results of the bacteriological observations in the 8 completed cases are presented in Table I.

TABLE I

Date of Culture		Strep. Hem.	Staph. Aureus
Case D. T. First Series, 10–10—10–21 Second Series, 11–18—12–16			
10–14	Both tonsils	++	0
10–28	Both tonsils	0	0
11–14	Both tonsils	+++	0
	Pharynx	+++	+
11–18	Both tonsils	+++	0
	Pharynx	+++	0
12–5	Both tonsils	++	0
	Pharynx	++	0
12–12	Both tonsils	+++	0
	Pharynx	0	0
12–16	Both tonsils	0	0
	Pharynx	0	0
Case E. H. First Series, 10–8—10–12 Second Series, 12–3—12–23			
9–28	Both tonsils	++	0
	Pharynx	0	0
10–21	Right tonsil	+	0
	Left tonsil	0	0
	Pharynx	0	0
12–2	Both tonsils	++	0
	Pharynx	++	0
12–9	Both tonsils	++	0
	Pharynx	0	0
12–16	Both tonsils	0	0
	Pharynx	0	0
Case H. C. First Series, 10–13—10–24 Second Series, 11–30—1–7			
10–12	Both tonsils	+	+
	Pharynx	0	+
10–19	Both tonsils	+++	0
	Pharynx	+++	0
10–28	Right tonsil	0	++
	Left tonsil	++	++
12–5	Both tonsils	0	+
	Pharynx	0	0
12–9	Both tonsils	0	++
	Pharynx	0	++
12–16	Both tonsils	0	+
	Pharynx	0	+
1–6	Both tonsils	0	0
	Pharynx	0	0

Case C. S. First Series, 9–26—10–4
Second Series, 11–1—11–25

9–24	Both tonsils	+++	o
9–30	Both tonsils	+++	o
10–7	Both tonsils	+++	o
10–28	Left tonsil	o	++
	Right tonsil and pharynx	o	o
11–4	Left tonsil	+	o
	Right tonsil	o	o
11–11	Both tonsils	+++	o
	Pharynx	o	o
11–18	Both tonsils	++	o
	Pharynx	o	o
11–25	Right tonsil and pharynx	+	o
	Left tonsil	o	o
1–9	Both tonsils and pharynx	o	o

Case B. T. First Series, 10–1—10–11
Second Series, 1–1—11–17

9–30	Both tonsils and pharynx		
10–7	Both tonsils	+++	o
10–28	Left tonsil	+++	o
	Right tonsil and pharynx	+	o
11–4	Both tonsils and pharynx	o	o
11–11	Both tonsils and pharynx	o	o
11–18	Left tonsil	+	o
	Right tonsil and pharynx	o	o
12–19	Both tonsils	++	o
	Pharynx	o	o

Case B. S. First Series, 9–26—10–4
Second Series, 11–1—12–3

9–24	Right tonsil	+++	+++
	Left tonsil	o	++
9–30	Right tonsil	o	+++
	Left tonsil	++	++
10–7	Left tonsil	+	o
	Right tonsil	o	+
10–28	Left tonsil	++	o
	Right tonsil and pharynx	o	o
11–11	Both tonsils	++	o
	Pharynx	+	o
11–18	Both tonsils	+	o
	Pharynx	o	o
11–25	Both tonsils	+++	o
	Pharynx	o	o
12–2	Right tonsil	+	o
	Left tonsil and pharynx	o	o
12–9	Left tonsil	+	o
	Right tonsil and pharynx	o	o
1–9	Right tonsil	+	o
	Left tonsil	++	++
	Pharynx	+	o

Case W. R. First Series, 9–27—10–10
Second Series, 11–1—12–9

9–26	Both tonsils	o	o
9–30	Both tonsils	o	o
10–7	Right tonsil	+++	o
	Left tonsil	o	o
10–28	Both tonsils	+++	o
	Pharynx	o	o
11–11	Left tonsil	++	o
	Right tonsil and pharynx	o	o
11–18	Both tonsils	o	o
	Pharynx	o	o
11–25	Both tonsils	++	o
	Pharynx	o	o
12–2	Both tonsils and pharynx	o	o
12–9	Both tonsils and pharynx	o	o
1–9	Left tonsil	o	+
	Right tonsil	++	o
	Pharynx	o	o

Case A. S. First Series, 9–26—10–4
Second Series, 11–1—12–3

9–24	Both tonsils	o	o
9–30	Both tonsils	o	++
	Pharynx	o	o
10–7	Right tonsil	o	+
	Left tonsil	No record	
10–28	Right tonsil	o	+
	Left tonsil	o	o
	Pharynx	+	o
11–11	Both tonsils and pharynx	o	o
11–18	Both tonsils and pharynx	o	o
11–25	Right tonsil	+	o
	Left tonsil and pharynx	o	o
12–2	Both tonsils and pharynx	o	o
12–9	Both tonsils and pharynx	o	o
1–9	Both tonsils and pharynx	o	o

In the above tabulations, +++ indicates the presence of the organism in question in the proportion of at least one colony to four of the normal flora. The presence of not more than ten colonies on a plate containing from one hundred to three hundred or more colonies is indicated by +. Intermediate ratios are recorded as ++.

DISCUSSION

Certain outstanding features will at once become apparent upon even the most casual perusal of the above tables. Of 8 patients who received the full course of eight radiations, 5 were free from the hemolytic streptococcus and staphylococcus

aureus at the time of the final cultures. Of these 5, 3 may be considered as incomplete studies, inasmuch as a control set of cultures was not taken at the end of at least four weeks following the last treatment. Two patients were therefore free from the bacteria under consideration, after the lapse of a considerable interval following treatment. These have not again been observed to determine whether this freedom persists. Three patients continued to yield to hemolytic streptococcus and staphylococcus aureus in large numbers at the end of the stated interval, and this, despite the fact that with two of them there was a certain tendency for the hemolytic streptococcus to disappear during the two courses of treatment. In the other case, the carrier state appeared and persisted in an individual (W. R.) whose flora was at first free from the organisms. The tenbency for the organisms to disappear during the treatment is also illustrated by the incomplete cases, but consideration of the cases W. R. and B. S. will show how fallacious it would be to draw conclusions without the aid of later control cultures.

From the point of view of the individuals concerned, this 40 per cent success, of the permanence of which we have even now no assurance, can scarcely be regarded as dramatic. Six of the 8 individuals harbored the hemolytic streptococcus upon the surface of the tonsils before the institution of irradiation. Of the remaining two, one showed a moderate number of the organisms one month after treatments were ended. This may be regarded as a definitely bad result, viewed from the standpoint of prophylaxis. The other yielded the organism at various times during the course of the treatments, and it is attractive to presume that the tonsillar crypts in this case acted as foci from which the bacteria occasionally made their way to the surface. The observations of Pilot and Davis,[3] who succeeded by the swab method in culturing the hemolytic streptococcus in only 61 per cent of cases from hyperplastic tonsils (which, after enucleation, yielded positive cultures from the crypts in 97 per cent) bear directly upon this point. Of similar import are recent observations of Davis,[4] and of Bloomfield,[5] that serial swabs from the throats of normal individuals will eventually reveal the presence of these organisms. Similarly, we have no proof that, in the 2 cases from which we were apparently successful in banishing the pernicious elements of the flora, they did not continue to exist in secluded pockets not reached by the ordinary swabbing. It is entirely reasonable that serial quantitative cultures from these children's throats would eventually disclose the undesirable organisms in either or both. The case A. S. was never heavily infected at any time, and perhaps of the entire group is the only example of a persistent approximately harmless flora. This individual may therefore be disregarded in our quest for an excellent result, upon the ground that he never showed a marked deviation from the normal. We are thus reduced to one example only of really marked improvement!

The above discussion has been presented as to its findings on the presence or absence of the hemolytic streptococcus. As pointed out above, of the other definitely pathogenic organisms encountered, only the staphylococcus aureus was ever present frequently enough in any one individual to entitle it to serious consideration. In the case A. S., it appeared in small numbers during the course of the first series of treatments, only to disappear again. In the case H. C., it was persistently present during the entire series of cultures with the single exception of the final set. This case has already been considered as one presenting a definitely encouraging improvement, but we have no proof that swabs taken tomorrow would not be loaded with this organism. As for the case B. S., his plates showed many colonies of this pathogen at the start, and its persistence one month after the termination of his course of treatments shows that the apparent eradication of the organism from his flora during the period of irradiation was essentially misleading.

Further comment seems unnecessary. The study of the changes in the surface flora offers no indication that reduction by radiation in the size of hyperplastic tonsils is necessarily accompanied by any diminution of the potentialities as foci of infection. Viewed from this angle, they

continue to menace the health of the individual, perhaps to as great a degree as before. And for this very portentous reason, it may well be questioned to what degree we are justified in abandoning careful tonsillectomy, with its certain eradication of these foci, in favor of mere reduction in the size of the tonsils through the agency of the roentgen ray.

SUMMARY

Eight cases treated with two courses of four radiations each are discussed from the point of view of the bacterial flora of the tonsils and pharynx. Seven were found definitely to harbor the hemolytic streptococcus. Three are regarded as incompletely studied. In three other cases, the hemolytic streptococcus persisted at least four weeks following the termination of treatment. Of the remaining two, one presented an approximately normal flora throughout. The other may be regarded as improved from the bacteriological point of view, but there is no proof that this improvement is persistent.

There is no evidence that reduction in the size of hyperplastic tonsils by irradiation is accompanied by eradication of the carrier state in individuals harboring the hemolytic streptococcus in these tonsils.

GENERAL CONCLUSIONS

1. Roentgenotherapy causes a decrease in the size of chronically infected tonsils and adenoids, particularly in the large cellular glands, and less so in the small fibrous glands.

2. Our experience indicates that roentgenotherapy will not cause the hemolytic streptococcus to disappear permanently from the surface of the crypts of the tonsils, but will cause a small percentage of the palpable glands at the angle of the jaw to disappear. Out of 14 cases on which we have notes, one case, R. C., showed the palpable glands completely disappeared. In 3 cases the glands were barely palpable, and in 2 cases the glands on the left side disappeared, and were still palpable on the right side. In the other 8 cases the glands were unaffected.

3. Clinically, roentgenotherapy gives relief from symptoms, but this may be only temporary. In some cases, the objective signs of the chronically infected tonsils do not disappear after this treatment; that is, the size of the tonsils is unchanged, hemolytic streptococcus is still present, and the glands of the neck are palpable, although subjectively they are well. In the arthritis case mentioned above, this improvement might be due to the tonic effect of the *x*-ray.

4. Generalized use of *x*-rays for treatment of chronically infected tonsils and adenoids is not advisable.

Practically 100 per cent of chronic carriers of hemolytic streptococcus and diphtheria can be cured by operative removal of tonsils and adenoids. *X*-ray and radium treatment must be effective in an approximate percentage, and at the same time more comfortable than operation, and be associated with fewer complications.

5. The *x*-ray treatment of tonsils and adenoids is especially indicated in those cases where a surgical operation is inadvisable—such as chorea, pulmonary tuberculosis, and cardiac and renal lesions. It is our impression that the greatest field of usefulness will be in the treatment of children. Children rarely have a chronic infection of the tonsils comparable to that of adults. Their tonsils and adenoids are very cellular and of the type that responds most readily to roentgenotherapy. Their symptoms are largely due to hypertrophy of the lymphoid tissue in the throat and nasopharynx. It is possible that when the technique is perfected, roentgen-ray or radium treatment will entirely supplant surgical measures in children.

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SOME PROBLEMS OF RADIATION THERAPY*

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A PERUSAL of the literature on the subject of radiation therapy reveals the difficulty of comparing doses of radiation used by different radiologists. The reason for this lies in the more rapid empirical development of the *art* as compared with the *science* of radiation therapy. In the present paper are given some generalizations which facilitate the comparison of skin doses given under different conditions of treatment. They are based on the results of experiment, and corroborated by clinical observations.

I. FILTRATION

The sources of radiation at our disposal are the *x*-ray tube and radioactive substances. In either case the radiation emitted is very heterogeneous. An *x*-ray bulb emits radiation of many different wave-lengths, ranging from a minimum wave-length, which is determined solely by the maximum voltage applied to the tube. This is true no matter whether a fluctuating or constant voltage is used. A radioactive source such as radium, emits three entirely different types of radiation, each of which is heterogeneous. The necessity of filtering the radiation is due to its heterogeneity. This is especially important in deep therapy, where the tumor to be treated is surrounded entirely by healthy tissue, through which the radiation must necessarily pass.

Like any other substance, tissue absorbs radiation of long wave-length more easily than it does radiation of short wave-length. Therefore, if the incident beam is heterogeneous, the soft, or long wave-length components will be absorbed to a greater extent by the tissue than the hard, or short wave-length components. As a result, the radiation which reaches the deeper layers of tissue will be, *on the average*, harder than the initial beam.† The superficial layers of tissue will receive a larger dose of radiation than the deeper layers, for the following reasons: 1. The surface layer receives radiation which is more easily absorbed, and therefore absorbs a larger percentage of the amount falling on it. 2. The deeper layers receive radiation which is more penetrating, so that a smaller fraction of the amount reaching the respective layers is absorbed by each than by the first layer. 3. As some of the radiation has been absorbed by the superficial layers, a smaller amount reaches the deeper layers. 4. There is an additional diminution due to the greater distance from the source at which the deeper layers are. For the present, however, we shall not consider the effect of distance.

Examining more closely the above factors, we find that to overcome the first two difficulties, we need radiation which is absorbed to the same extent by successive layers of tissue. It is the aim of proper filtration to accomplish this result. The third difficulty can never be overcome entirely, because, no matter what kind of radiation is used, if it is to produce an effect, it must be absorbed to some extent by the tissue. However, the more penetrating the radiation is, the larger will be the dose delivered to the deeper layers for the same skin dose. We may conclude, then, that for deep therapy the radiation used should be homogeneous and as penetrating as possible.* We shall consider now how far these requirements can be satisfied in practice.

The most penetrating radiation available for therapeutic purposes is emitted by radioactive substances. However, they emit also softer gamma radiation and beta rays, which, in comparison, are easily absorbed by tissue. For deep therapy it is necessary to use a filter of sufficient thickness to remove at least all the beta rays.

* A Leonard Prize Paper.

† Of course the wave-length of the hardest component of the unfiltered and filtered beams is the same. Matter cannot affect radiation in such a way as to shorten the wave-length.

* The effect which the quality of radiation used may have on the physiological effect produced is not definitely known at the present time. It seems, however, that within wide limits of wave-lengths the biological effect is independent of the quality of radiation.[1]

On the other hand, as we shall see presently, practical considerations make it undesirable to use such filters as will allow only the most penetrating gamma rays to reach the tumor. In the first place, human tissues are made up principally of chemical elements of low atomic weight. Accordingly, the decrease of the intensity of radiation, as the latter traverses the tissue, is due primarily to the scattering effect of the atoms, and not to true absorption.[2] As the scattering effect is nearly the same for radiation of different wave-lengths,[3] the penetration in tissue of gamma rays of different wave-lengths is not very different. Therefore, it is possible to have a heterogeneous beam of radiation which is absorbed exponentially by tissue. That is, each successive layer of tissue will absorb substantially the same fraction of the radiation reaching it.

The relative amounts of radiation of different wave-lengths *emitted* by radioactive substances are determined by the radioactive changes which take place spontaneously. As these cannot be influenced by any means at our disposal, we cannot change the emission of radiation, either as regards quality or quantity. The use of a filter to remove the softer components of the radiation results necessarily in a decrease of the intensity of radiation. The same is true of *x*-rays, for, with a given machine and voltage used, the type of radiation emitted is also fixed. Accordingly, for economical reasons, it is important not to use excessive filtration. The proper filter to use can be determined experimentally.

In a previous paper[4] was described the experimental procedure for the determination of a suitable filter for deep radium therapy. It is unnecessary, therefore, to give the details here. It should be noted, however, that animal tissue was used as the absorbing medium to test the radiation passing through each filter. The criterion for correct filtration was the exponential absorption of the filtered radiation by tissue, as indicated by the absorption curves, when plotted to a semi-logarithmic scale. The proper thickness of filter was less than 2 mm. of brass, or its equivalent; but for convenience, 2 mm. was adopted. A secondary filter of low atomic weight, such as a few mm. of rubber, must be used in addition to the brass, in order to remove the soft secondary radiation emitted by the metal.[5]

The experimental apparatus used to determine the effect of different filters on the *x*-rays emitted by a Coolidge tube

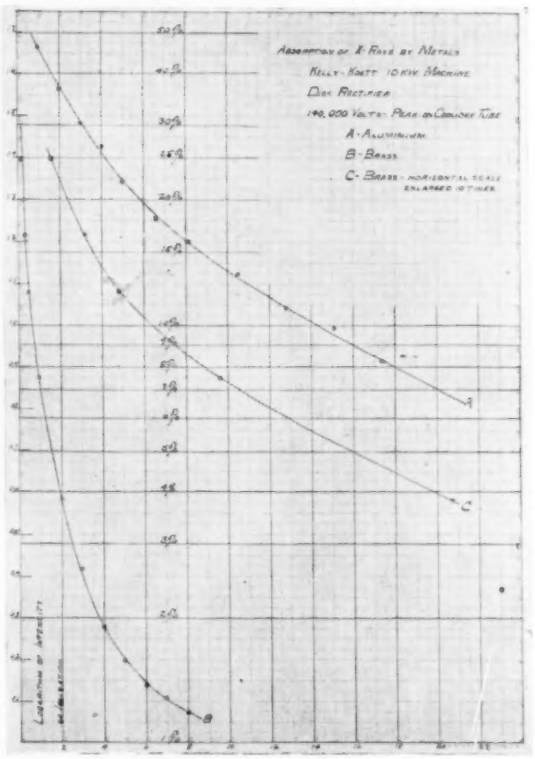

FIG. 1.

operated at 140,000 crest voltage was similar to the one used for radium rays. Here, however, the conical ionization chamber had to be at a greater distance from the source, on account of the glass bulb and the high voltage. The thin mica window was larger, so that larger slices of meat had to be used for the tests. On this account more of the scattered radiation entered the chamber, and the values of the absorption coefficients are not comparable to those obtained previously for radium rays.

In Figure 1 are given the aluminum and brass absorption curves for *x*-rays produced by a voltage whose crest value,

as measured by a sphere gap, was 140,000 volts. The curves are plotted to a semi-logarithmic scale, and therefore the fact that they are not straight lines shows that the *x*-radiation of these experiments is not absorbed exponentially by aluminum or brass. The decreasing slope of these curves with increasing filter thickness shows that the radiation becomes gradually more penetrating as the filtration increases. This should be contrasted with the straight lines obtained in the case of radium rays beyond a filter of 2 mm. of brass or 6 mm. of aluminum, showing that further filtration did not increase the penetrating power of the transmitted gamma rays appreciably. From the curves we obtain the thicknesses of the two metals corresponding to the same ionization in the measuring instrument. They are given in Table I. The first column shows the

TABLE I

Per Cent Radiation Transmitted	Thickness Brass Mm.	Thickness Aluminum Mm.	Ratio
25.6	0.15	4	26.6
22.2	0.20	5	25.0
19.5	0.25	6	24.0
16.0	0.34	8	23.6
13.5	0.43	10	23.2
11.8	0.53	12	22.6
9.0	0.77	16	21.8
7.1	1.05	20	19.1

percentage ionization produced by the radiation passing through the filters, taking the ionization produced by the unfiltered radiation as 100 per cent. It should be noted that since the quality of the radiation is affected by the filter, strictly speaking, these figures do not represent the relative *amounts* of transmitted radiation. The last column shows the ratio between corresponding thicknesses of aluminum and brass. If these metals absorbed radiation of different wave-lengths in the same proportion, the ratios of thicknesses would be all the same. It will be seen, however, that for lightly filtered radiation, brass is relatively more effective as a filter than aluminum, since the ratio is larger for the thinner filters than for the thicker ones. Therefore brass* is a better filter for the *x*-rays of these experiments because it absorbs relatively more of the soft and less of the hard radiation, in comparison to aluminum. This effect is due to the fact that the decrease in the transmitted beam due to scattering is nearly the same for all wave-lengths within wide limits,[6] and in the light elements like aluminum the scattering plays a more important part than in heavier elements.

In connection with the filter thicknesses given in Table I it should be emphasized that the thicknesses and brass of aluminum which correspond to the same ionization, cannot be said to be "equivalent." As already stated, brass absorbs relatively more of the soft radiation, and therefore, while the ionization is the same in both cases, the quality of the transmitted radiation is slightly different. For practical purposes, however, the values of Table I can be regarded as equivalent thicknesses.

In Figure 2 are given the curves showing the absorption of filtered *x*-radiation by tissue. They are drawn in their correct relative positions. The slope of the different curves, which determines the coefficient of absorption (that is, the percentage of radiation absorbed per cm. of tissue) is appreciably different. To compare the penetrating power in tissue of the rays filtered through different thicknesses of metal it is best to calculate the absorption coefficients for the parts of the curves which are straight. They are given in Table II. It will be seen that the coefficient of absorption decreases steadily with increasing filtration up to 1 mm. of brass, the heaviest filter used in these experiments. This means that the penetration of the filtered radiation increases considerably (column 3). However, the amount of radiation transmitted by the filter as measured by the ionization (column 4) decreases more rapidly. Accordingly, the time of treatment to give the same skin dose (column 5) increases markedly. It is evident from these results that no general conclusion can be reached as to the neces-

* Commercial brass may contain a considerable percentage of lead, whereas copper is usually free of impurities. Since lead is very objectionable as a filter for *x*-rays because it absorbs abnormally the shorter wave-lengths, copper is preferable for therapeutic purposes. Our experiments show that copper and zinc have substantially the same absorbing power as brass.

sary and sufficient filter to employ with this type of roentgen radiation. The requirements of the particular case to be treated, as well as practical considerations and limitations, must be taken into account. It is probable, however, that 0.5 mm. of brass is a sufficient filter for the deepest

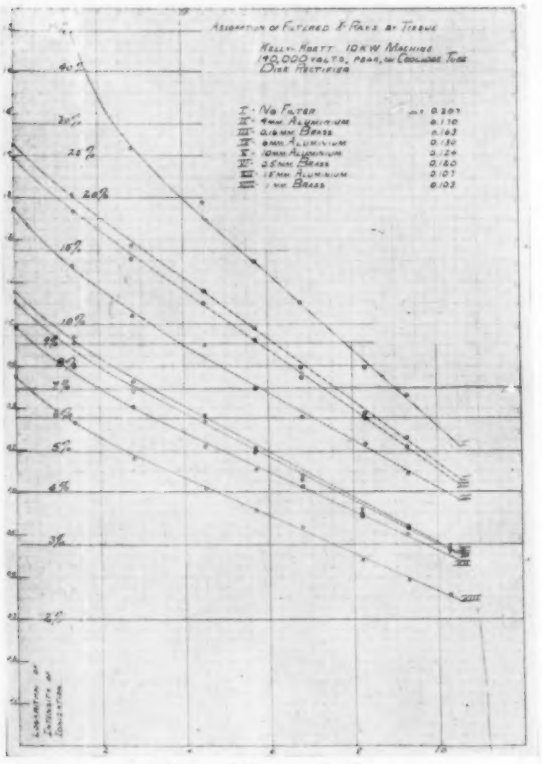

FIG. 2.

radiation therapy which would be attempted with this voltage.

The difficulty experienced in deciding what is the most suitable filtration for the *x*-rays of these experiments does not exist in the case of radium rays. The conclusion reached is that 2 mm. of brass is sufficient as a primary filter, and actually this is a little more than the minimum necessary thickness. The reason for this lies in the composition of the heterogeneous beam of radiation which we wish to filter in the 2 cases. The radiation emitted by ordinary radium containers consists of beta and gamma rays. The beta rays are easily absorbed by matter and can be eliminated by a filter of 2 mm. of brass. The gamma rays include a wide range of wave-lengths, but the distribution of energy in their spectrum is such that a filter of 2 mm. of brass removes all the soft radiation, and the transmitted radiation is of much shorter wave-length than ordinary *x*-rays. In other words, the range of wave-lengths present in *x*-rays is inconspicuous in gamma rays. Therefore there is a sharp change in the quality of the transmitted radiation occurring at a point between 1.5

TABLE II

1		2	3	4	5
Filter		Coef. of Absorption, Cm.[1]	Half Val. Thickness, Cm.	Per Cent Rad. Trans. by Filter	Time of Exposure
Metal	Mm.				
Al.....	4.0	0.170	4.08	26.6	1.0
Brass.....	0.16	0.163	4.25	24.9	1.07
Al.....	6.0	0.130	5.33	18.8	1.41
Al.....	10.0	0.124	5.60	12.0	2.21
Brass.....	0.5	0.120	5.77	11.4	2.33
Al.....	15.0	0.107	6.47	9.90	2.77
Brass.....	1.0	0.103	7.50	7.50	3.53

and 2 mm. of brass filter. While the radiation passing through this filter is still heterogeneous, it is made up of such short wave-length components that it is absorbed exponentially by tissue. The reason for this, as already mentioned, is that under such conditions the scattering by the light atoms of which tissue is made up, and not the true absorption, is the predominant effect. In the case of *x*-rays the energy in the spectrum[7] is distributed differently. The shorter components, including the characteristic radiation of tungsten, are very strong, and therefore the increase in penetration with filter is more gradual. If we were to push the filtration to the point where the characteristic radiation is absorbed out, we would have hardly any radiation left.

Brass has been selected as the most suitable filter for deep radium therapy, not only on theoretical grounds but for practical reasons. Theoretically any metal of medium atomic weight and of the proper thickness is satisfactory. Brass is convenient because it is cheap and is easily

worked. Metals of high atomic weight, like lead, are not as economical because they absorb relatively more of the penetrating radiation, even if the minimum required thickness is used. For treatments where space is an important factor, however, platinum is to be preferred, because a smaller thickness suffices. Brass, or better, copper, is recommended as a filter for *x*-rays because the scattering effect on the shorter wave-length components is not so pronounced in comparison as when aluminum is used. Metals of high atomic weight are unsuitable as *x*-ray filters, since they absorb abnormally the short wave-length components. This point is clearly brought out by some of Duane's spectra.[7] Other things being equal, the filter which gives the largest amount of penetrating radiation should be used, for this makes the treatments shorter. For our purposes brass or copper fulfil this condition, both in the case of radium and *x*-rays.

II. ERYTHEMA DOSES FOR DIFFERENT FILTRATION

Considering the absorption curve for radium radiations, using brass as the absorber, we may assume at first that it enables us to compare doses of radiation given under different conditions of filtration, provided the other factors remain the same. That is, if we take the ionization produced by the radiation from the bare emanation tube as 100 units, the absorption curve gives us the relative values of the ionization produced by radiation filtered by different thicknesses of brass. Thus, for a filter of 0.5 mm. of brass, the ionization is 15 units. We might think, therefore, that the mc.-hour dose to produce the same skin effect as the bare tube would be $^{100}/_{15}$ or 7.3 times larger, other conditions remaining the same. This, however, is not the case. It was decided, therefore, to determine the mc.-hour doses which produce the same skin effect under different conditions of filtration empirically, by making suitable tests on the skin of many patients.

The experimental conditions for these tests were as follows: In a cork 4 cm. in diameter and 2 cm. high, a hole 2 cm. in diameter was bored. A thin silk ribbon was fastened across the top, and a slot was provided into which the brass filters were fitted. As secondary filters, disks of pure gum rubber were used, fitting into the hole of the applicator to make up the desired thickness. The source of radiation was, in every case, a tube of radium emanation 14 mm. in length and 0.5 mm. in external diameter, whose value in mc. was known accurately. It was fastened to the silk ribbon with a little paraffin, so that it was always at a distance of 2 cm. from the skin of the patient. This distance was adopted in order to minimize errors due to possible slight variations in the distance of application. The applicator is shown in cross-section in Figure 3.

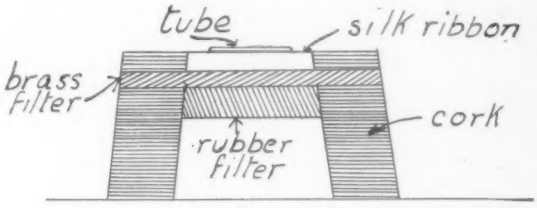

FIG. 3.

A skin erythema was adopted as the effect which we wished to produce by radiation of widely different quality. In general, this is very indefinite, for everyone has a different idea of an erythema dose. However, special precautions were taken to insure uniformity and reliability of results. In the first place, we used the skin erythema as a biological indicator, not as a measure of the radiation effect. At the present time, it is impossible to use any biological effect of radiation in any other way than as an indicator. For instance, if we irradiate an animal with a suitable dose of *x*-rays we produce certain blood changes. Then we irradiate a similar animal with double the dose previously employed, all other conditions, biological as well as physical, remaining the same. The blood changes which result and which we can determine, do not enable us to tell that double the dose of *x*-rays was used on the second animal. We may be able to say that a stronger dose was given, qualitatively, but not quantitatively. The same is true in the case of skin erythema. It is also very difficult to compare erythema effects on different

patients, or even on the same patient, and be able to tell whether they are of the same intensity or not, especially when the comparison is not made at the same time.

To overcome these difficulties we proceeded as follows: It is well known that the degree of erythema produced on the skin of different patients by the same dose of radiation is not generally the same. Therefore, there must be a dose of radiation such as will produce no visible effect on the skin of the less radio-sensitive patients, and a slight, but definite effect on the skin of the more radio-sensitive patients. If we adopt this type of reaction as our standard of comparison we can eliminate almost entirely the personal element on the part of the observer. In the experiments it was only necessary to determine whether an erythema did or did not appear following the application of a certain dose of radiation to the skin of many patients. If no erythema appeared on all patients tested, the dose was too low; if every patient showed an effect, the dose was too high. By repeated trials it is possible to determine the dose which produces an effect on 50 per cent of all the patients, while the others show no apparent effect, the individuals treated being chosen at random. To be sure of such a dose, however, it is necessary to test a large number of patients in each case, for doses differing slightly from each other. Bearing in mind the practical applications of these experiments, it is evident that such extreme refinement is unnecessary. Accordingly it is sufficient to determine the dose which produces a definite erythema in the majority of patients, but still produces no visible effect on a certain percentage of the individuals treated. The latter point is very important, because it indicates that the dose is not too high, without relying on the intensity of redness observed.

It may be contended that one observer may see an erythema where another does not. In these experiments such errors were negligible because, on account of the type of applicator used, the small area affected by the radiation was completely surrounded by normal skin. Another precaution consisted in making the tests always on the same part of the body—the volar aspect of the forearm, immediately below the antecubital fossa—on account of the different sensitivity exhibited by different skin areas of the same individual. Differences due to the age of the patient, complexion, general physical condition, etc., were taken account of by treating a large number of patients without selection. The doses arrived at, therefore, are for the average cancer patient. It should be mentioned also that the erythema on which the doses are based appears, as a rule, within the fourth week after radiation, but variations of one week earlier or later are not uncommon. In a considerable percentage of cases the erythema proceeds to the stage of bleb formation, and then subsides. This requires usually about a week. Then bronzing appears, and may persist for an indefinite period. In some cases it has been noticed distinctly eighteen months after the treatment. Telangiectases have never been observed following these tests. The texture of the skin months afterward is normal, even though slight pigmentation persists. The primary reaction, which takes place within the first week, bears no definite relation to the final effect, and therefore is unsuitable for our purposes. In some cases showing definite secondary effects there is no visible primary reaction. This is especially true when filtered radiation is employed. On account of the long time required for the maximum effect to manifest itself, the experiments have extended over a period of more than two years.

The actual experimental procedure may be summarized as follows: We wish to determine the erythema dose, as already defined, when the cork applicator of Figure 3 is used without filter, with the source of radiation previously described. The radiation traverses about 0.1 mm. of glass, the silk ribbon of the applicator, and a thin layer of paraffin before reaching the skin. It consists mainly of beta rays, and the effect will be mostly on the superficial layers of skin. We make some preliminary tests to determine the dose which will produce an effect on the skin. Then, by varying this dose slightly, and treating several patients with each slightly different dose, we determine the dose which pro-

duces the desired erythema. This dose is then checked on a larger number of patients. The same process is repeated for the case of filtered radiation, with each filter used. To facilitate the work of determining the erythema doses for filtered radiation, each patient was treated at the same time on the other forearm with a cork applicator without filter, giving the erythema dose previously determined for unfiltered radiation. By this means it was possible to tell whether the patient was especially sensitive to radiation or not. Then, by comparing the intensity of redness on the two arms, it was easier to arrive at the proper dose. The mc.-hour doses corresponding to different filters, obtained in this empirical manner, are shown in Table III.

TABLE III

Filter		Erythema Dose
Brass, Mm.	Rubber, Mm.	Mc. Hrs.
0.0	0.0	7.5
0.16	1.2	30.0
0.32	1.2	100.0
0.50	1.2	250.0
0.75	2.4	475.0
1.0	2.4	630.0
2.0	2.4	830.0

It will be noticed that between the mc.-hour dose for unfiltered radiation and that for radiation filtered by 2 mm. of brass and 2.4 mm. of rubber, there is a difference of more than 100-fold. On this account it would have been very difficult to have kept the time of application approximately the same for all the tests made. Actually, the applications with filtered radiation were considerably longer than with unfiltered rays; but, within the limits of time variation of these experiments, this had no detectable effect on the dose. Special tests were made before this conclusion was reached.

If we analyze the results of Table III, we find that the mc.-hour doses increase with the filter for two physical reasons: 1. The radiation reaching the skin through the filter is less in amount. 2. It is also more penetrating, and hence a smaller amount will be absorbed by the tissue. Since the biological effect is brought about by the radiation which is absorbed by the tissue, the mc.-hour doses of Table III are related to the radiation which is effective in producing the observed changes. Furthermore, in the tests, all the physical conditions but one—the filtration—were kept the same, and therefore the mc.-hour doses are inversely proportional to what we may call the "effective radiation" corresponding to the different filters. Taking the reciprocals of the mc.-hour doses we obtain figures which are directly proportional to the "effective radiation." For convenience, we may call the value corresponding to "unfiltered" radiation 100 units, and then the other values will represent in percentage the effective radiation for the different filters. Plotting these values we obtain curve B of Figure 4, which we may call the "biological absorption curve." It will be noted that a smooth curve can be drawn through the experimental points. Since each point was determined independently of any other by a series of skin tests, this shows that the biological reaction adopted

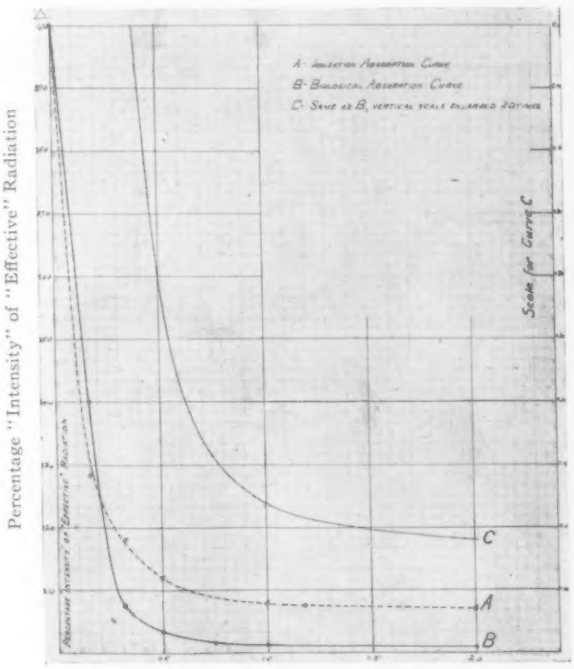

FIG. 4.

as a standard of comparison is quite definite and reliable for our purposes.

Having obtained this curve we can now define the standard erythema *objectively*. That is, it is that intensity of redness of the skin resulting from a radium application under the conditions described above, giving the dose which, on the biological absorption curve (or simply from Table III) corresponds to the filtration used. For instance, if a radium tube of 50 mg., whose total filtration is 2 mm. of brass, is available, it should be applied to the patient at a distance of 2 cm. (*center* of tube to skin surface) for sixteen hours to obtain the standard erythema. To make the conditions as nearly as possible like those of these experiments, the proper distance should be obtained by means of a cork support as already described, and the secondary filter should be 2.4 mm. of rubber. Tests should also be made on several patients, in order to get an idea of the average erythema obtained. If a thinner brass filter is available it should be used in preference to the thicker one, as the mc.-hour dose will be smaller and the test will be more convenient. However, the unfiltered radiation from a radium tube does not quite correspond to that from an emanation tube, because the glass is thicker and the salt itself absorbs more of the radiation. The dose here given for unfiltered radiation, therefore, cannot be checked by those who do not use the emanation.

It may be instructive now to compare the biological absorption curve with the one previously obtained by ionization measurements. The two are shown in Figure 4. In either case the ordinates, that is, the distance of any point on the curve from the scale of brass thicknesses, represent "effective" radiation. In one case it is the radiation which is effective in producing a skin erythema, and in the other, in producing ionization. Neither curve gives the *quantity* of radiation passing through the filters. This is due to the fact that the quality of the transmitted radiation changes very considerably with the filtration in the range of brass thicknesses here considered. Curve A was obtained with the ionization chamber described in the paper already referred to.[5] The effect on the ionization of the secondary rubber filters used with the different brass thicknesses of the skin tests has been included in this curve, since it is involved in the "biological" absorption curve. The additional filtration due to the rubber is very considerable for the thin brass filters, and should not be overlooked. If metals other than brass are used as filters, precautions must be taken to secure approximately the same quality of radiation as employed in the skin tests, in order to obtain the same results. The fact that rubber was used with all the brass filters is useful in this connection, since rubber tends to equalize the quality of the radiation transmitted through filters of different composition. Using radically different ionization chambers (including a very small one with thin mica walls) other curves were obtained which differed considerably from the above. Still none even approached the biological absorption curve. The difference is clearly brought out by the figures of Table IV.

TABLE IV

A	B	C	D	E
Filter, Mm.		"Effective" radiation		Ratio C/D
Brass	Rubber	Ionization	Erythema	
0.0	0.0	100.0	100.0	1.0
0.16	1.2	28.5	40.0	0.71
0.32	1.2	18.1	7.5	2.41
0.50	1.2	11.8	3.0	3.93
1.0	2.4	7.63	1.19	6.31
2.0	2.4	6.74	0.90	7.49

If we assume the intensity of radiation from the unfiltered radium emanation as measured by the two effects, ionization and erythema, to be 100 per cent, the other figures represent the other "intensities" of the filtered radiation in percentages. It will be seen from column E that the discrepancy between the two increases with the filter. For the last filter the difference is 749 per cent. Therefore if, knowing the erythema dose for unfiltered radiation, we had used the ionization

curve to determine the dose for radiation filtered by 2 mm. of brass and 2.4 mm. of rubber, the calculated dose would have been 7.49 times too small. On the other hand, if the calculation had been based on the gamma ray dose, the dose for unfiltered radiation would have been 7.49 times too large.

In considering the great discrepancy which exists between ionization measurements and the production of skin erythema, we should bear in mind that, in the range of filtration here considered, the radiation changes not only in quality, but in type. The unfiltered radiation is mostly of the beta type whereas the radiation filtered by 2 mm. of brass is wholly gamma. It is not surprising, therefore, that there should be no parallelism between ionization measurements and erythema effects in this case. Nor do the results disprove the statement usually made that the biological effects are dependent on the ionization, for in this connection we mean ionization in the tissues. Our measurements are based on ionization in air, since at present there is no method of measuring tissue ionization.*

In special cases where the quality of the radiation is not very different, there is a parallelism between biological effects and the ionization in a suitable chamber, as has been shown by Friedrich.[1] Bearing in mind that the radiation filtered by 2 mm. of brass is practically "homogeneous," as far as tissue absorption is concerned, it follows that we can extend the biological absorption curve to larger thicknesses of brass filter by ordinary ionization measurements without introducing serious errors.

III. DISTANCE

Filtration is only one of the factors which determine the dose of radiation delivered to a deep-seated tumor. The effect of distance is no less important. It is a consequence of the law of conservation of energy that the intensity of radiation emitted by a point source varies inversely as the square of the distance. The intensity of radiation at any point is defined as the amount of energy flowing per second through unit area (1 sq. cm.) perpendicular to the line of propagation. Whence if the source emits Q units of energy per second, the intensity of radiation at a distance d is

$$I = \frac{Q}{\text{area of sphere of radius d}} = \frac{Q}{4\pi d^2} = \frac{Q}{4\pi} \cdot \frac{1}{d^2}$$

Since the factor $\frac{Q}{4\pi}$ is always the same for a given source, the intensity I varies inversely as the square of the distance.

On account of the inverse square law, the radiation reaching the deeper layers of tissue is always less than the radiation falling on the skin even if we neglect the absorption entirely. The smaller the distance of the source from the skin, and the deeper the tumor, the greater will be the difference between the skin and tumor doses. If we could place the source at an

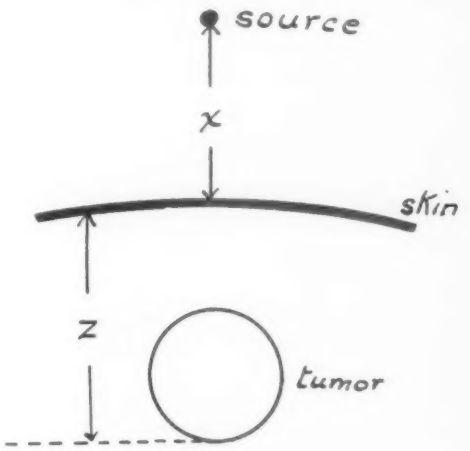

FIG. 5.

infinite distance from the skin, we would get parallel rays, and the intensity (which would then be infinitesimal) would be the same along the beam of radiation. The reason for this is that any infinite distance would then be negligibly small in comparison to the infinite distance of the source. We have here the clue to the practical solution of the problem. The condition to be fulfilled is that the difference between the distance from the source to the skin and the distance from the source to the tumor shall be small in comparison to either. This is evident from the following

* An attempt to overcome this difficulty led to the use of kerosene as the ionized medium. Even in this case, however, the absorption curve did not check curve B.

considerations: Let the relative positions of tumor, skin, and source be as shown in Figure. 5. Then the intensity on the skin is $I_x = \frac{k}{x^2}$, and the intensity at the back of the tumor is $I_z = \frac{k}{(x+z)^2}$, where k is a constant depending on the unit of radiation adopted. The difference between the skin intensity and the tumor intensity is $I_x - I_z = \frac{k}{x^2} - \frac{k}{(x+z)^2}$ To make this small for any given value of z, all we have to do is to make x very large in comparison. For instance, if $z = 1$, and we make $x = 100$, then $\frac{k}{100} - \frac{k}{101}$ is practically zero.

It will be seen that this relation will be true, no matter what unit of distance we adopt, provided that both x and z are expressed in the same unit. For a tumor 1 cm. deep, ($z = 1$ cm.) according to this example the distance of application would be 100 cm. ($x = 100$ cm.). For a tumor 1 *inch* deep, x would be 100 *inches*. For a tumor at any depth, x would be 100 times z. It is evident that the controlling element is the *ratio* between the intensity of radiation at the tumor and that at the skin; that is, the *fraction* of the skin dose which reaches the tumor. We can then plot a curve between these two ratios which will be of *general* applicability. It is shown in Figure. 6. At first a small increase in $\frac{x}{z}$ results in a large increase in $\frac{I_z}{I_x}$, but after $\frac{x}{z}$ reaches the value 11.8 the relative tumor dose, $\frac{I_z}{I_x}$, increases much more slowly. The curve never coincides with the 100 per cent line, but can be made to approach it as closely as we please by taking a large enough value for $\frac{x}{z}$. Practical considerations determine just how high we can afford to make the ratio $\frac{I_z}{I_x}$, since the time of exposure increases as the square of the distance x. If we wish to make it 90 per cent, the distance of application must be 19 times the tumor depth, *no matter what the latter may be.* It seems, however, that in practice it is hardly justifiable to try to obtain a better ratio than 80 per cent, corresponding to a value of $\frac{x}{z}$ of 8.5. For a tumor at a depth of 10 cm. the distance of application would then be 85 cm., which is already a considerable distance and entails a long exposure to obtain a skin dose.

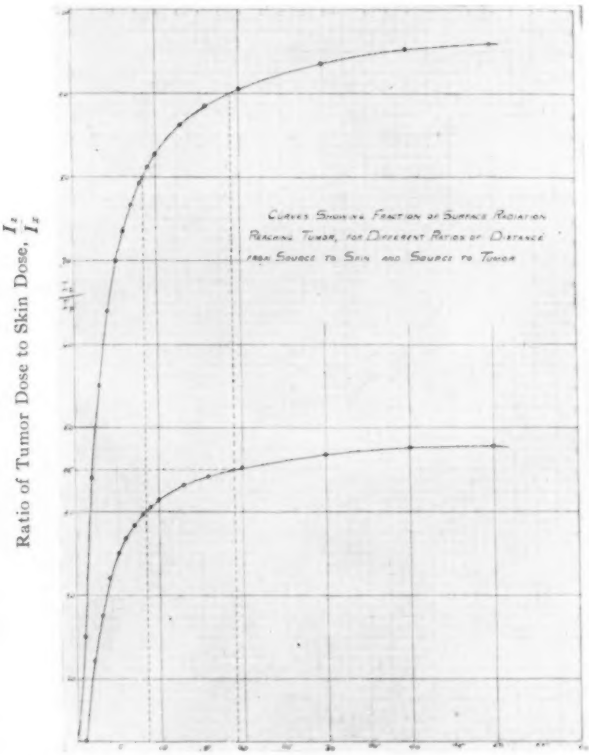
Curves Showing Fraction of Surface Radiation Reaching Tumor, for Different Ratios of Distance from Source to Skin and Source to Tumor
Ratio of Tumor Dose to Skin Dose, $\frac{I_z}{I_x}$
Ratio of Skin Distance to Tumor Distance $= \frac{x}{z}$

FIG. 6.

The absorption of radiation by tissue has no effect on the determination of the theoretical optimum distance of application. The reason for this is as follows: For deep therapy the source of radiation is always placed at a considerable distance from the skin.* Then the thickness of tissue z (Fig. 7) which affects the radiation reaching the back of the tumor is sub-

* If placed within the tumor the problem is evidently different, and presents no *physical* difficulties.

stantially the same for all rays entering the tumor, no matter how far the source may be. Even the volume of radiated tissue is nearly the same, if the proper diaphragm is used. Consequently the decrease of radiation due to the intervening tissue, and the scattering effect are the same for all practical distances of application (when the same quality of radiation is used).

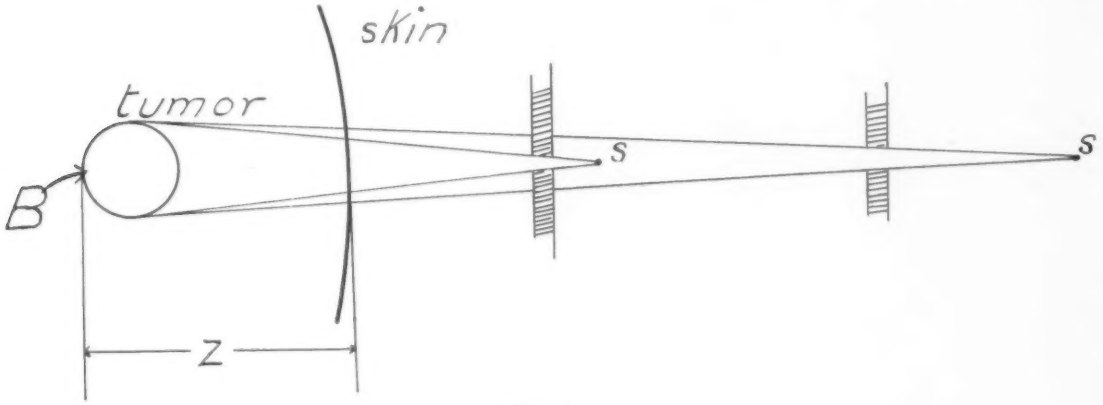

FIG. 7.

The effect of absorption on the curve of Figure 6 is simply to lower the 100 per cent line and every point on the curve in the same proportion. It amounts really to a decrease of the scale of $\frac{I_z}{I_x}$. Suppose, for instance, that the radiation reaching the point B (including primary, scattered, and secondary radiation) for any one position of the source is 50 per cent of what it would be if the tissue were not present. Then the maximum *relative* amount that we could ever get by placing the source at a very long distance is $\frac{50}{100} I_z$. For any other distance the value of $\frac{I_z}{I_x}$ can be obtained from the dotted curve which approaches as a limit the 50 per cent line. Thus for a value of $\frac{x}{z}$ of 19, the value of $\frac{I_z}{I_x}$ is 45, which is again 90 per cent of the possible maximum for this case, that is, $\frac{45}{50} = 90$ per cent. Hence for any given set of conditions (distance, depth of tumor, quality of radiation, etc.), the upper curve can be used to determine the difference in the amounts of radiation received by the skin and tumor from the operation of the inverse square law. The decrease due to the intervening tissue is additional and quite independent of that due to the relative distances of skin and tumor from the source. In practice, economy of time is an important factor to consider. Therefore such a combination of filter and distance (as well as other factors) should be used as will give the desired amount of radiation at a given depth with the minimum expenditure of energy. If we know the effect on the deep dose of each factor which influences it separately from all the others, we can best arrive at the proper combination.

The curve of Figure 6 can be used for either *x*-rays or radium, provided the linear dimensions of the applicator are so small in comparison to the distance of application that the source of radiation can be considered to be a point. In *x*-ray work this is always the case because the focal spot on the target is very small. But in deep radium therapy this is seldom the case, and should never be. Here large applicators are used, and they are placed rather close to the skin. The latter is a limitation imposed by the scarcity of radium. The inverse square law holds only for a point source. But in a distributed source it holds for every point of that source. This furnishes the method of attack for the solution of the problem. Since this paper was first written, one of us has published[8] curves which make

it possible to determine the mc.-hour doses for different applicators, placed at different distances from the skin. It is unnecessary, therefore, to describe the method and results in the present paper. However, it may be well to emphasize certain points. 1. In taking account of the decrease of radiation due to the filter of the applicator, the "biological" absorption curve was used. This makes it possible

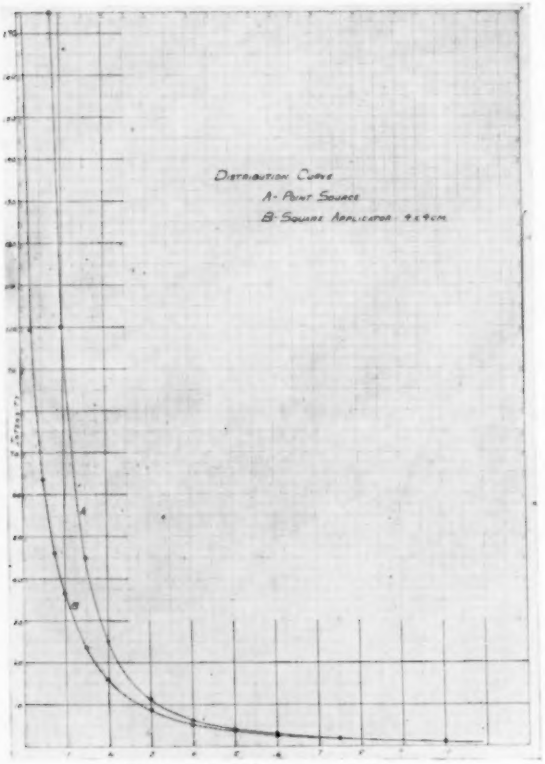

FIG. 8.

to work out curves for applicators having a filter less than 2 mm. of brass. In this range of filtration the radiation is very far from being homogeneous, and in addition to the absorption by the filter the absorption by tissue of the transmitted radiation from different parts of the applicator must be taken into account. 2. The curves given are of general applicability; that is, they can be used for applicators of widely different shape, size, and filter. Considering the large number of applicators of various shapes and sizes used by different workers in this field, and the amount of labor involved in the "point by point" calculations, the desirability of a general solution of this problem for practical purposes is obvious.*

The method of arriving at the "general" curves may now be described briefly. Taking a square applicator 4 × 4 cm., with a filter of 2 mm. of brass and 2.4 mm. of rubber, containing a given amount of radium, we can calculate the "intensity" of radiation at different distances from the radium by the point by point method. We can then plot the curve B of Figure 8. If the amount of radium in the square applicator were concentrated at its center we would have a point source and the inverse square law would give us curve A.

It will be noticed that beyond a distance of 8 cm. the two curves practically coincide. In other words, at a distance of 8 cm., the 4 × 4 cm. applicator can be considered as a point source. This conclusion does not depend on the unit of length adopted, for this is equivalent to changing the scale of the curves and does not affect their relative position. If the applicator were 4 × 4 in. it could be considered a point source when placed at a distance of 8 in. The necessary condition is, therefore, that it be placed at a distance of 2 times its linear dimension. Similarly the variation from the point source curve will be the same for any square applicators at distances which are the same multiple of the linear dimensions of the applicators. That is, at a distance of 4 cm. from a square applicator 4 × 4 cm., the radiation is 5.4 while at a distance 4 cm. from a point source it is 6.4 arbitrary units. The amount of radiation delivered by the square applicator at a point 4 cm. away from it is then $\frac{5.4}{6.4} = 84$ per cent of the radiation at the same distance due to a point source of the same strength. If now we take an applicator 8 × 8 cm. at a distance of 8 cm., it will deliver also 84 per cent of the radiation which a point source would deliver at a distance of 8 cm. Therefore, in order to have a general curve which can be used for

* Data and curves for definite applicators have been worked out by other investigators 9, 10, 11, 12. These, however, are not "general," so that the calculations have to be repeated for each applicator. Furthermore, they apply only to gamma ray treatments. The reader should consult these papers for gamma ray doses delivered at different tissue depths.

any square applicator we must (1) express the distance from the radium in terms of the side, a, of the applicator, and (2) express the amount of radiation at different distances as a percentage of the radiation delivered at the same distance by a point source of the same strength. Such curves are given in the paper already referred to for tubular, circular, square, and rectangular applicators having the following filters:

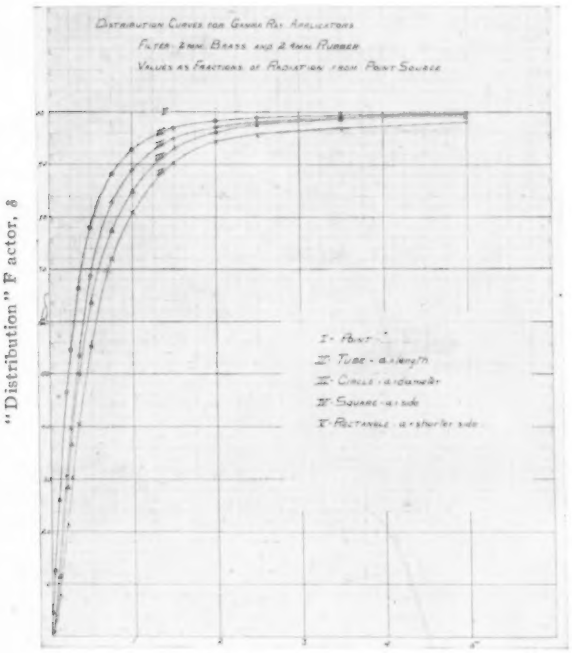
Distribution Curves for Gamma Ray Applicators
Filter: 2 mm. Brass and 2 mm. Rubber
Values as Fractions of Radiation from Point Source
I - Point
II - Tube - a = length
III - Circle - a = diameter
IV - Square - a = side
V - Rectangle - a = shorter side
"Distribution" Factor, s
Distance, in Terms of a

FIG. 9.

None; 0.16 mm. brass and 1.2 mm. rubber; 0.5 mm. brass and 1.2 mm. rubber; 0.75 mm. brass and 2.4 mm. rubber; 2 mm. brass and 2.4 mm. rubber. The set of curves for 2 mm. brass and 2.4 mm. rubber is given also in Figure 9 to illustrate a further application of such curves in the next section of this paper.

As previously mentioned, in deep radium therapy we cannot place the applicator at a favorable distance on account of the small amount of radium available. Our main reliance in this case is on the penetrating power of the gamma radiation. The curves of Figure 9, however, enable us to determine the effect of distance alone on the amount of radiation reaching different depths. An example will illustrate this point. Given an applicator 4×6 cm., which is placed at a distance of 5 cm. from the skin, what is the relative amount of radiation reaching a depth of 3 cm. below the skin, neglecting absorption by the tissue? The relative distances in terms of a are shown in Figure 10. From the curve for the rectangle, Figure 9, we find at $0.5\,a$ the radiation is 55.0 per cent of the point source value. At $1.25\,a$ the radiation is 85.4 per cent of the point source value. The

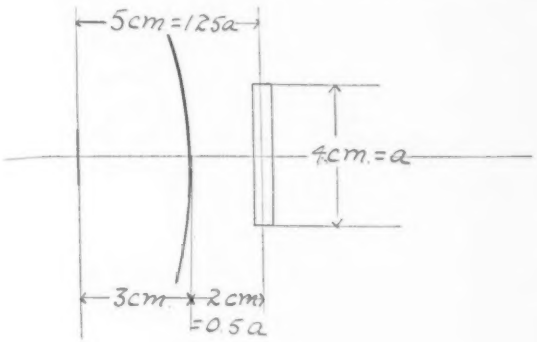

FIG. 10.

intensity of the radiation for the point source can be calculated according to the inverse square law. Thus at 2 cm. the intensity is $\frac{k}{2^2}$ arbitrary units; at 5 cm. it is $\frac{k}{5^2}$ arbitrary units. Hence for the rectangle we have;

On skin surface

$$\frac{k}{2^2} \times 55.0$$

At depth of 3 cm.,

$$\frac{k}{5^2} \times 85.4,$$

neglecting tissue absorption, and the radiation at a depth of 3 cm. is

$$\frac{\frac{k}{5^2} \times 85.4}{\frac{k}{2^2} \times 55.0} = \frac{85.4 \times 4}{55.0 \times 25} = 24.8 \text{ per cent of}$$

the amount falling on the skin. If a point source had been used it would have been $\frac{2^2}{5^2}$ or 16 per cent.* From this we see the advantage of a distributed source when applied close to the skin. An additional

* If we included the absorption of the radiation by the 3 cm. of tissue we would get a still smaller fraction of the skin radiation at the given depth.

advantage is due to the fact that the radiation from the large applicator is distributed more evenly over the skin surface immediately under it.

IV. SKIN DOSES

The important physical conditions which determine the physiological effect on the skin are (*a*) the strength of the source of radiation; (*b*) its distribution; (*c*) the filtration; (*d*) the time of exposure; (*e*) the distance; (*f*) the absorption of radiation by the skin. The strength of the source is expressed in mgm. of radium element or in mc. when the emanation is used. The time of exposure is usually expressed in hours. The radiation *emitted* by the source in any given time is then kx (mg.) x (hours)

$$k \times (\text{mg.}) \times (\text{hours})^* \qquad (1)$$

where k is a constant of proportionality depending on the units adopted. The amount of radiation reaching the skin varies directly as the quantity emitted, and depends on factors (*b*), (*c*), and (*e*). The physiological effect on the skin depends on the amount of radiation reaching it and the percentage of this which it absorbs,—factor (*f*). We can now set up an expression for a skin dose, involving the above six factors.

For a point source without filter the radiation falling on 1 sq. cm. of skin directly below the applicator may be represented by

$$R = k \frac{(\text{mg}) \times (\text{hours})}{(\text{cm.})^2} \qquad (2)$$

when the distance of the source from the skin is expressed in cm. When the source is not a point the radiation reaching the same square cm. of skin is less than the value obtained from expression (2). Therefore we should introduce a numerical factor δ, less than unity, to take into account the effect of the distributed source. The equation then becomes

$$R = k \frac{(\text{mg.}) \times (\text{hours})}{(\text{cm.})^2} \times \delta \qquad (3)$$

Values of δ for applicators of different shapes and sizes can be obtained from the curves explained in the previous section and published in a separate paper.

If a filter is used the value of R will be still less because some of the radiation emitted is cut out by the filter. A factor ϕ can be used to denote the fraction of the emitted radiation which passes through the filter. Hence

$$R = k \frac{(\text{mg.}) \times (\text{hours})}{(\text{cm.})^2} \times \delta \times \phi \qquad (4)$$

It should be noted that the "distribution" factor δ is not independent of the filtration, and therefore its value must be determined from the curves corresponding to the filter in the applicator.

Equation (4) represents the amount of radiation reaching the skin for any practical applicator placed at any distance from the skin. However we are mainly interested in the biological effect which this radiation produces. For practical purposes skin erythema is a convenient effect to use as a guide in dosage. Furthermore the experiments described in Section II indicate that an erythema as there defined is suitable as a standard of comparison. If then we take this as our unit skin dose we have:

Skin dose =

$$\frac{q\,(\text{mg.}) \times (\text{hours})}{(\text{cm.})^2} \times \delta \times \phi \times \psi \qquad (5)$$

where ψ is the fraction of the radiation falling on the skin which is effective in producing the erythema, and q is a constant of proportionality. For our purposes we need not have separate values of ϕ and ψ. The biological absorption curve of Section II enables us to determine values of the product of $\phi \times \psi$ corresponding to different brass filters. We may denote this as one factor, α, and the formula for a skin dose becomes:

Skin dose =

$$\frac{q\,(\text{mg.}) \times (\text{hours})}{(\text{cm.})^2} \times \delta \times \alpha \qquad (6)$$

Before equation (6) can be used to solve actual problems, it is necessary to determine the value of the constant q. At the Memorial Hospital several applicators have been used for a number of years, so that the respective mc.-hour doses required to produce a mild erythema are known with considerable accuracy. If we take the skin dose delivered by one of these applicators as one unit, we can determine

* The emitted radiation can also be expressed in "mc. destroyed." [13]This notation, which is used mostly in France, has no real advantage over the mgm.-hour notation.[14]

the value of q in equation (6). Thus, for an applicator 4×5 cm., having a filtration equivalent to 2 mm. of brass, and with the radium placed at a distance of 3 cm. from the skin, the dose necessary to produce a mild erythema is 2,000 mgm.-hours. The value of δ for a source 4×5 cm. placed at a distance of 3 cm. can be obtained from Figure 9. It is 0.75. The value of α is 0.0090 according to the biological absorption curve of Figure 4. Substituting in equation (6) we get

$$1 = q \times \frac{2{,}000}{(3)^2} \times 0.75 \times 0.0090$$

whence

$$q = 0.66$$

We can make use of the data for the other applicators in the same way and thus arrive at an average value for q. Table V shows the values of q corresponding to five different applicators. It will be seen

TABLE V

Applicator	Size, Cm.	Distance		Mc. Hrs.	Distrib. Factor, δ	Absorp. Factor, α	q
		Cm.	× a				
"Tray"....	4×5	3	0.75	2,000	0.75	0.0090	0.66
"Pack"....	8×12	6	0.75	9,000	0.72	0.0090	0.61
"Pack"....	8×12	10	1.25	20,000	0.85	0.0090	0.64
"Block"...	4×6	4	1.0	3,200	0.81	0.0090	0.68
Cork.....	1.4×0.05	2	1.43	830	0.96	0.0090	0.56
						Average value of q =	0.63

that the agreement among the first four is certainly as good as can be expected in this work. The skin doses for these applicators were determined empirically by the clinicians using them, and are entirely independent of any curves in this paper. The value for the cork applicator is appreciably lower than the others. This, however, is as it should be, since a skin erythema results from treatments with the above applicators only in the minority of cases. It will be remembered that in the skin tests with the cork applicator an erythema developed in the majority of patients. This dose, therefore, is a little higher than the one used in our clinical work. If we take the average value of q from Table V, equation (6) will give us the proper doses for therapeutic purposes. The final equation is

$$\text{Skin dose} = 0.63 \frac{(\text{mg.}) \times (\text{hours})}{(\text{cm.})} \times \delta \times \alpha \qquad (7)$$

It should be noted that the filtration for all the applicators of Table V is such as will give only gamma radiation, and is equivalent to 2 mm. of brass plus a suitable secondary filter. The data from the skin tests with less filtration are not included because they would not give us independent values of q, on account of the fact that the absorption factor, α, is determined from these tests. To obtain as reliable a value for q as possible it would be desirable to use data for large applicators with light filtration. But the skin doses for such applicators corresponding to the above gamma ray doses are not known. It is safe to say, however, that the equation will give the correct doses even for lightly filtered applicators of considerable size, and placed fairly close to the skin. Tests are being made to check the accuracy of the equation for applicators placed very close to the skin. Until this work is completed, while the equation may give us the correct doses even in extreme cases, we should not expect it. The equation can be used with confidence for all gamma ray applicators because these are always placed at a distance from the skin. Another point which deserves mention is that equation (7) does not take into account the "intensity" of the treatment, that is, the effect of the length of the treatment on the biological reaction. That this has some influence, no one doubts, but the extent is not known. Some of our skin tests showed that, as long as the number of mgm.-hours is the same, the amount of radium and the time can be varied within wide limits without appreciable effect on the degree of erythema. A similar conclusion is also reached by Kroenig and Friedrich in their work with *x*-rays.[1] In practice, therefore, this factor can be neglected.

If we wish to calculate the mgm.-hour dose which we should give with a certain applicator to produce a mild erythema on the average patient, equation

(7) can be written in a more convenient form:

$$\text{mg.} \times \text{hours} = 1.59 \frac{(\text{cm})^2}{\delta \times \alpha} \qquad (8)$$

The values of α corresponding to different brass filters, obtained from the biological absorption curve, are given in Table VI.

TABLE VI

Filter, Mm.		α
Brass	Rubber	
0.0	0.0	1.0
0.10	1.2	0.62
0.20	1.2	0.26
0.30	1.2	0.085
0.40	1.2	0.050
0.50	1.2	0.030
0.60	1.2	0.0210
0.80	2.4	0.0145
1.00	2.4	0.0119
1.25	2.4	0.0105
1.50	2.4	0.0098
1.75	2.4	0.0094
2.00	2.4	0.0090

If any filter other than brass is used, its absorbing power in terms of brass must be determined. This can be done approximately by means of curves published by one of us.[5] In such determinations account must be taken of the quality of the transmitted radiation. This point is clearly brought out in the paper referred to. The values of δ for any particular applicator and distance of application can be determined from the curves explained in Section IV. Since δ varies according to the size of applicator, distance, and filtration, it is not practical to give its values in tabular form. Here also the filter is to be reduced to the equivalent brass thickness. In addition, if the thickness is not the same as one of those for which curves have been plotted, the value of δ has to be obtained by interpolation.

Equations (7) and (8) are based on the unit erythema dose used at the Memorial Hospital for gamma ray applicators. If any one wishes to use his own unit, he can do so simply by redetermining the value of the constant q from his own data.

We shall now give a few examples to illustrate the uses of equations (7) and (8):

Example 1. A five-hour treatment is given with 100 mg. of radium in an applicator 4 × 4 cm. at a distance of 2 cm. from the skin, the filter being 2 mm. of brass and a few mm. of rubber or similar material. What is the skin dose given? First we have to determine the value of δ for this applicator when placed at a distance of 2 cm. The side of the square is 4 cm., therefore the distance of application is ¾ or 0.5 in terms of the linear dimension of the applicator. From the curve for the square applicator in Figure 9 we find that for a distance of 0.5 *a* the value of δ is 0.63. The value of α according to Table VI is 0.0090. Hence

$$\text{Skin dose} = 0.63 \times \frac{100 \times 5}{(2)^2} \times 0.63 \times 0.0090 = 0.45 \text{ of an erythema dose.}$$

Example 2. With the applicator of the previous example we wish to given an erythema dose. How long must the treatment be? Using equation (8), we have

$$\text{mg.} \times \text{hours} = 1.59 \times \frac{(2)^2}{0.63 \times 0.0090} = 1{,}120.$$

Therefore the time of exposure must be $1{,}120/100$ or 11.2 hours. The same answer could have been obtained by a simple proportion from the data of the previous example. For, if the 500 mgm.-hour treatment corresponds to 0.45 of an erythema dose, to give a full dose under the same conditions we must use $\frac{500}{0.45}$ or 1,110 mgm.-hours.

Example 3. We wish to administer an erythema dose in four hours with an applicator 4 × 5 cm. at a distance of 3 cm., the filtration being the same as in the preceding examples. What quantity of radium must we employ? In Figure 9 there is no curve for rectangular applicators of the proportions of the one used in this example. However we can obtain the value of δ by interpolation. We note that the given applicator is bigger than *a* square 4 × 4 cm. and smaller than a rectangle 4 × 6 cm. From the curves of Figure 9, corres-

ponding to a distance of ¾ or 0.75 a, δ is 0.77 for the square and 0.72 for the 4×6 cm. rectangle. Therefore, to a sufficiently close approximation the value for the 4×5 cm. rectangle is 0.75. The value of α is as before 0.0090. Hence from equation (8)

$$\text{mg.} \times 4 = 1.59 \frac{(3)^2}{0.75 \times 0.0090} =$$

2,100 or mgm. = 525.

The applicator of this example is the same as the first one in Table V, for which the mgm.-hour dose, empirically determined, is 2,000. The discrepancy between this and the calculated dose, 2,100 mgm.-hours, is small, and is due to the fact that the value of q in the equation is an average value, and not the one which we obtained for this applicator.

Example 4. If in Example 1, the filter had been 1 mm. of brass and 2.4 mm. of rubber, what dose would have been given? On account of the length of the present paper, applicator curves for filters other than 2 mm. of brass are not included. By referring to a previous publication[8] we find that we have curves for 0.75 mm. of brass filter, but not for 1 mm. To determine the value of δ we must have recourse to interpolation. From Example 1 we know that δ = 0.63 for 2 mm. of brass. From the 0.75 mm. curves we find that δ = 0.55. Referring to the biological absorption curve, we find that the "effective" radiation values are 0.0157, 0.0119, and 0.0090. Hence, as a filter, 1 mm. of brass stands practically midway between 0.75 and 2 mm. Then, if we take the arithmetical average of the two values of δ we obtain a value which is sufficiently accurate for our purposes, $\frac{0.55 + 0.63}{2} = 0.59$. The value of α (Table VI) for this filter is 0.0119. Therefore,

Skin dose =

$$0.63 \times \frac{100 \times 5}{(2)^2} \times 0.59 \times 0.0119 = 0.55$$

This paper as originally written, included an equation for x-ray skin doses similar to equation (7). It is not given here for two reasons: The paper is already too long, and we hope to make the equation of more general applicability. That is, the equation was applicable only to the 10-in. machines then in general use for deep therapy. Now that higher voltages are being employed, it is desirable to modify the equation so as to include these voltages. This will be done as soon as we have obtained sufficient clinical experience with the new machine. Also, a complete report of the skin tests will be made later by one of us. The results given here are only those needed for the development of equation (7).

SUMMARY

I. The problem of *filtration*, for both roentgen and radium rays, is discussed, and conclusions are reached based on experimental evidence. The criterion for correct filtration is the exponential absorption of the radiation by tissue. Therefore, raw beef muscle, which has essentially the same absorbing power as human tissue, was used to test the quality of variously filtered radiation.

1. (*a*) For x-rays, filtration increases the average penetration of the radiation steadily.

(*b*) For x-rays produced by 140,000 volts (crest) a change of filter from 4 mm. of aluminum to 1 mm. of brass makes the radiation nearly twice as penetrating and increases the time of exposure 3½ times, other conditions remaining the same. A table is given showing the quality of the radiation for intermediate filters.

(*c*) "Equivalent" thicknesses of brass and aluminum are given for different degrees of filtration. From these we see that brass is the better material to use as filters for x-rays. Brass, zinc, and copper have the same absorbing power, and can be used interchangeably.

2. (*a*) For radium rays filtration increases the penetration, but, beyond a small initial filter, much less rapidly than in the case of x-rays.

(*b*) The amount of radiation coming through the filter decreases considerably with thickness of filter.

(*c*) From (*a*) and (*b*) we conclude that in practice it is not advantageous to push the primary filtration beyond 1.5 or 2 mm. of brass. An additional filter of low atomic weight must be used to remove the soft secondary radiation.

3. For deep therapy the radiation should be absorbed exponentially by tissue and should be as penetrating as possible.

II. The question of erythema doses is discussed.

(*a*) It is shown that we can use skin erythema as a biological *indicator* with considerable accuracy.

(*b*) Making use of this fact, skin tests on many patients were made, from which a "biological" absorption curve for brass and rubber filters was determined.

(*c*) The results of the skin tests enable us to define a unit erythema dose *objectively* in terms of the physical factors of the skin tests.

(*d*) Comparing the "biological" absorption curve with an ionization absorption curve, we find that there is no parallelism between ordinary ionization measurements and erythema effects when radiation changes from a preponderance of beta rays to gamma rays.

III. The problem of *distance* in radiation therapy is considered in detail.

1. (*a*) A general curve is given from which the most advantageous practical distance of application can be obtained for any depth of tumor. This can be used for either *x*-rays or radium when the applicator can be considered a point source.

(*b*) It is shown that the distance of application should be considered with respect to the depth of the tumor. When the distance is 19 times the tumor depth, the amount of radiation reaching the tumor is 90 per cent of the amount falling on the skin, due *solely* to the "*dispersion*" of the radiation. For a tumor 10 cm. deep this would place the source at a distance of 190 cm. from the skin, which is, of course, impractical. If we are satisfied with a ratio of 80, the source may be placed at 8.5 times the tumor depth. This question must be decided by each individual worker.

2. On account of the scarcity of the element, radium applicators are never placed at the most advantageous distance from the skin. Here, reliance is placed on the greater penetration of gamma rays to obtain a favorable ratio between the skin and deep doses.

3. (*a*) General curves are given for tubular, circular, square, and rectangular applicators having a filter of 2 mm. of brass and 2.4 mm. of rubber. From these we can determine the relative amounts of radiation at different distances from a gamma ray applicator of any size. Similar sets of curves for thinner applicators are given in a previous paper.

(*b*) In the calculations for these curves, use was made of the biological absorption curve. This made it possible to determine the curves for lighter filtration than 2 mm. of brass.

(*c*) From these curves we conclude that when the applicator is placed at 3 or more times its linear dimension from the skin, for practical purposes it may be considered to be a point source, as far as the axial radiation is concerned. The curves give the variation from a point source for any distance.

(*d*) The advantage of a distributed source over a point source for deep radium therapy is brought out.

IV. The problems of *skin doses* is discussed in detail, and equations of general applicability are given.

1. (*a*) For radium rays the equation is

$$\text{Skin dose} = q \times \frac{(\text{mc.}) \times (\text{hours})}{(\text{cm.})^2} \times \delta \times \alpha$$

where q is a factor of proportionality depending on the unit of dose adopted. δ is the distribution factor, values of which, for different gamma ray applicators may be obtained from the curves of Figure 9. α is the absorption factor, values of which may be obtained from the biological curve of Figure 4.

(*b*) The value of q corresponding to the unit of skin dose adopted, that is, a slight erythema, is 0.63. The equation then becomes

$$\text{Skin dose} = 0.63 \times \frac{(\text{mc.}) \times (\text{hours})}{(\text{cm.})^2} \times \delta \times \alpha$$

and can be used to determine the skin dose under different conditions of application.

(*c*) If a different unit of skin dose is adopted, a new value for q must be obtained to conform with it. This can easily be calculated as indicated in the paper.

2. (*a*) The accuracy of the general equation worked out in this paper is shown by

the close agreement of the values of q among themselves. These were determined from widely different physical conditions of treatment, independently of any curves or tables given in this paper. The doses were determined empirically by clinicians, and are based on their experience in treating a large number of patients.

V. In the work presented in this paper it has been the rule not to draw conclusions from *physical* experiments unless they were substantiated by clinical experience. The necessity for this precaution is brought out by the data of Table VI.

In conclusion we wish to express our indebtedness to the staff of the Memorial Hospital for their kind cooperation in this work, and to Mr. James Sarros for his assistance in making some of the calculations and curves of this paper.

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THE EFFECTS OF ROENTGEN RAYS AND RADIOACTIVE SUBSTANCES ON LIVING CELLS AND TISSUES*

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THE following is a summary of the more important effects of roentgen rays and radioactive substances on living matter: 1. There are intrinsic sources of radioactivity within the body. Zwaardemaker especially draws attention to the fact that potassium, an important constituent of the body, sends out penetrating beta rays and gamma rays. He believes that potassium in the body fluid exercises its functions by means of its radioactivity, —an opinion which has not remained uncontroverted, and which recent studies have made improbable.

Lazarus-Barlow has shown that in certain individuals, especially in a number of those affected by cancer, there is a residue of radium emanation. It is present not only in the cancer itself, but may be found even in other tissues of such individuals.

2. If we compare the action of radiation on a great variety of isolated cells, tissues and whole organisms, we may discern the factors which determine the degree of sensitiveness of living matter to radiation. They are in the main as follows:

(*a*) Actively dividing cells are considerably more sensitive than resting cells and tissues. (*b*) Cells or tissues consisting of simple protoplasmic material in which a nucleus is embedded are much more sensitive than cells which are embedded in a large amount of transformed cell protoplasm, or in products of cell secretion, fibers and paraplastic material in general. (*c*) Especially resistant are entirely resting cells or tissues, especially if they have been dehydrated. (*d*) Tissues which are generally more resistant to all kinds of injury are likewise usually more resistant to radiation. In some cases, active division of cells may be the expression of great vigor; and in these cases cells which tend to divide actively may be more resistant than the same kind of cells in a less active condition; for the same reason cells with a simpler structure may be more resistant than more differentiated cells of a related

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character. There may be, in addition, a species difference in the sensitiveness of analogous tissues, which may be quite considerable.

3. Radiation affects cytoplasm as well as nucleus. But interference with the nucleus is usually of much greater significance for the functioning of the cell than localized changes in the cytoplasm. The lesion of the nucleus becomes apparent in its consequences very much more readily. The nucleus is a more delicate reagent. In addition, it may be that weaker intensities of radiation may solely affect the nucleus. Again, there exist differences between different kinds of cells in the comparative readiness with which cytoplasm and nucleus are affected.

4. There is a graded series of effects of radiation on cell functioning. The most delicate and intricate functions are affected by the smallest quantity of radiation. The coarser functions require larger doses. If we begin with the most delicate function, we can arrange the functions in the order of their sensitiveness as follows:

(*a*) A transmission of species differentials and of hereditary factors in general. These depend upon the proper functioning of the chromosomes. During mitosis cells are especially sensitive, and more particularly during the metaphase of mitotic division. (*b*) Processes of differentiation and growth of the most delicate and most differentiated organs like eye and brain. (*c*) Processes of differentiation and growth of the more simple and basic organs and tissues. (*d*) Motor activity of cells (ameboid, ciliary movements, movements of spermatozoa). (*e*) Oxydation processes as expressed in CO_2 production. (*f*) The visible structure and life.

5. According to the intensity of the radiation we may further grade the action of the rays. Weak intensities may stimulate motility, excitability of nerves and metabolism; greater intensities may weaken or destroy them. The same holds good in the case of growth processes.

Growth processes, especially, lend themselves to further differentiations of the actions of radiation. In some cases a period of stimulation of growth is followed by a period of depression and death. In these cases more severe injuries become apparent after a preceding latent period. Again, a first period of retardation in growth may be followed by a subsequent acceleration. The accelerating effect becomes apparent after early injurious consequences have disappeared, or after substances produced through radiation have become sufficiently diluted to act as a stimulant.

A further gradation is possible of the weakening or inhibiting effects of radiation on growth. All degrees of retardation of growth are possible. Conditions intermediate between cell death and full growth vigor may be maintained for some time, but usually this condition of intermediate growth energy represents an unstable equilibrium which tends to pass either into full vigor, when after a temporary depression the tissue regains its full growth, or into cell death and, in the case of tumors, into absorption. In the case of the cancers, transplantation into a new host is specially liable to stimulate the regaining of full growth vigor after a temporary depression. It is, however, probable that under special conditions, which are unfavorable to the vigorous activity of cells, without being destructive, cells may remain in an intermediate stationary condition for considerable periods of time.

6. These graded effects on growth are not peculiar to the action of roentgen rays and of alpha, beta and gamma rays, but are very similar to the effect which we had previously found in tumor cells, exposed *in vitro* to the action of heat, and subsequently transplanted into living animals.

7. The intensity of radiation which is required for these graded effects varies with the sensitiveness of the cells and tissues upon which it acts. The doses are much smaller in the case of sensitive tissues. A dose stimulating a sensitive tissue may be without effect in the case of a more resistant tissue. A dose which is stimulating in the case of a more resistant tissue may already be inhibiting in the case of a more sensitive tissue.

8. A summation may take place between the effects of radiation and of unfavorable factors within the cell. This summation

may convert an otherwise stimulating dose into a depressing one, or it may convert an otherwise depressing dose into a destructive one. A summation may also occur between the effects of radiation and experimentally produced injuries of a different kind, like those produced through heat (Bovie, Rohdenburg and Prime).

9. In the case of certain effects of radiation, a latent period separates the time of application of the rays and that of the appearance of the first manifest consequences—stimulation or depression. The duration of the latent period varies approximately inversely with the intensity of radiation. A latent period may be absent, in case the intensity of radiation used is very great. It may be lacking in the case of certain cell functions, production of CO_2, motor activity and even cell division. The latent period depends either on the fact that during embryonic development the most delicate adjustments appear last in the developing organism and that with a weak intensity of radiation only the most delicate mechanisms are affected; or it depends upon the occurrence of what we would call "chain reactions," one injurious change being the cause of a succeeding injury of a different character; gradually the total effects of these injuries may become very severe.

10. The effect of the various kinds of rays does not differ in a way corresponding with their fundamental physical differences. The positively charged alpha particles do not have an effect diametrically opposed to the negatively charged beta particles; but essentially the difference between the effects of various rays is of a quantitative nature; in the case of all of them, relatively small doses may stimulate, while large doses injure. The character of stimulation and injury depends on the character of the living system which they affect more than on the character of the rays. Alpha rays have the most severe effects and may cause structural changes in cells kept *in vitro*, when beta and gamma rays would not produce such changes. Beta rays may cause directly a localized necrosis of the brain, whereas gamma rays merely produce lesions of the blood-vessels and hemorrhage (Bagg). But these are essentially differences of a quantitative nature; in principle the effects of these radiations on living matter are the same. There is reason for assuming that only those particles or rays are effective which are held back within the cell.

11. There are indications that through repeated radiations an immunization of tissues against the effect of radiation can take place. This has been especially observed in radiation in the case of tumors and leukemia. It may depend on the formation of new cell races more resistant than the old ones; a formerly depressing dose may thus become a stimulating one if acting on a more resistant cell or tissue. This immunity is presumably an acquired cell immunity; but the problem needs further investigation.

12. All we have said so far about tissues in general applies equally in the case of cancers, with the additional statement that cancers are especially vulnerable for several reasons: (*a*) Cancer cells are dividing rapidly. (*b*) They are often dividing rapidly under abnormal conditions, as demonstrated by irregularities in the cell divisions and irregularities in arrangement and character of cells. This is probably due to the presence of unfavorable conditions, as for instance, an inadequate relation between vascularization and expansion of the tumor, or to the presence of a growth stimulus which is overactive, if measured by the metabolic function of the cells. (*c*) The rapid cell multiplication prevents or retards the production of paraplastic structures in the tumor which tend to protect the cells, and to make them less sensitive. In the case of cancers a summation of internal unfavorable factors and of the effects of radiation takes place, and thus makes them more vulnerable than normal tissues. Those parts of the tumor in which the conditions are most unfavorable, namely, the central ones, usually succumb first. Otherwise we find parallel differences in the resistance of various kinds of tumors and of the normal tissues from which they developed. Thus lymphocytes are very sensitive to radiation; correspondingly, lymphosarcoma is relatively vulnerable. The simple basocellular carcinomata are

more sensitive than the more differentiated keratinizing squamous cell carcinoma. The fibrosarcoma which is richer in paraplastic structures is more resistant than the round cell sarcoma which is poor in fibrillar substance.

In addition, there is probably in the case of cancers the same factor of a specific resistance involved which we noticed in the case of normal cells and tissue, and which to some extent may counteract otherwise unfavorable conditions, like active cell division.

There are indications that in the case of tumors also the lesion of the nucleus plays a prominent part in the destruction of the cell. Morphologically, swelling of nucleus and cytoplasm and vacuolization of the latter are the most prominent changes following radiation (Ewing, Alter). This is succeeded by destruction of the cells. Lesser degrees of injury in more resistant tumors may lead to an acceleration of keratinization and to the production of relatively inactive cystic or gland-like formations (Alter).

13. The effect of radiation on tumors is primarily a direct one, acting on the tumor cells themselves. Only secondarily do the ingrowth of connective tissue and increased fibrosis come into play. But it is very probable that while in the case of normal, vigorously growing tumor cells the influence of the host connective tissue is not sufficiently strong to hold effectively in bounds the cancerous tissue, it might be able to do so, at least for a longer or shorter period, if the tumor had previously been weakened in growth energy. Under these unfavorable conditions the tumor cells might ultimately die, or their recovery might be retarded. In experiments in which the transplantable tumors were used in testing the effects of radiation, the transplantation itself acted as a stimulus which would be lacking in spontaneous tumors in man. The effect of radiation on tumors is in many respects similar to the effect of heat on tumors. We have observed that a tumor whose growth energy has been experimentally diminished through heating, may regain its full growth energy after transplantation. The same may take place in the case of radiation (F. C. Wood).

Possibly lymphocytes may contribute to a certain extent to the injury of the radiated tumors. However, in the case of tissues belonging to the same individual,—and spontaneous tumors are of such a character,—lymphocytes are usually not attracted. But it may be that if for any reason tumor cells have been injured and changed in their metabolism, they may in some respects behave like strange tissues of another individual and attract lymphocytes. However, exact investigations on this point are, as yet, lacking.

14. There exist certain other indirect effects of radiation which may have to be considered in estimating the influence of radiation on tumors. Murphy has shown that it is possible to increase the number of lymphocytes in animals through a small dose of soft roentgen rays. He showed, furthermore, that the immunity against tumors may be increased with an increase in the number of lymphocytes and diminished with a decrease in the number of these cells. It must, however, be stated that these effects may perhaps be very weak or absent in certain cases, and that they were not noticeable in the experiments of Prime. Murphy also showed that radiation of a tissue with soft roentgen rays increases the number of lymphocytes in this tissue and *pari passu* makes it unsuitable for transplantation of tumors. However, we must hesitate to apply directly these results to radiation of human tumors. In the case of the latter we have to deal with well-established autochthonous tissues of the same character as the tissues among which they live, while in the former we have to deal with transplanted tumors. Now during the first phase following transplantation the tumors are much more accessible to injurious influences than later, when they are well established. Furthermore, in most cases we have to deal in these experiments with strange tumors which originated in a strange organism. Our investigations have shown that the degree of relationship between host and transplant is the deciding factor in the destructive activity which the lymphocytes may bring to bear on the tissue. Their activity is almost nil, if the transplanted tissues are identical in origin with the lymphocytic tissue of the host.

In the case of a spontaneous tumor, lymphocytes would, therefore, not be very active. It is, of course, possible that here also radiation, either of the affected individual or of the tumor, might somewhat change the relationship between tumor and host, and this may perhaps explain why Murphy found a certain immunizing effect of radiation even in the case of autotransplantation of spontaneous tumors. However, as stated, we are not aware of a noticeable effect of an experimentally produced increase in lymphocytes on a spontaneous, not transplanted, tumor.

We cannot, therefore, apply these experiments, interesting as they are in themselves, to the effect of radiation on spontaneous human tumors; or at least we must make certain reservations which limit their applicability. Nevertheless it is possible that even in spontaneous tumors lymphocytes may play a seondary part in injuring the radiated cells.

15. In appraising the effects of radiation on tumors we must, therefore, take into account the indirect effects of radiation which depend upon reactions of the host tissue against the tumor, as well as the direct effects on the tumor cells; among the former the connective tissue reactions are probably of the greatest importance. Lymphocytes may play a certain rôle.

It is furthermore, possible, that as the result of radiation, the body fluids may be modified in such a way that growth processes are affected thereby. Thus it has been observed that states of cachexia or intoxication following radiation may influence unfavorably the means of defense of a rayed individual against tumor growth. Murphy showed in a mouse the development in the blood of a substance which favors the growth of lymphocytes following the application of a small dose of soft roentgen rays.

Radiation of pieces of tumor *in vitro*, with subsequent transplantation of the radiated piece into the living animal, may differ from radiation in the living organism in several respects: (*a*) Radiation of the surrounding tissue and even of the more distant organs may exert a certain effect which is lacking *in vitro*. (*b*) The radiated piece of tumor is less active during the time of radiation *in vitro*, where the conditions of oxydation and nourishment are less favorable than *in vivo*. A diminution in the activities may possibly diminish the sensitiveness of the tumor cells to radiation. (*c*) Transplantation practised in these experiments may have a certain stimulating effect on tumor growth. (*d*) Radiation *in vitro* eliminates the action of the scattered rays which may surpass in intensity the direct rays.

16. The toxemia following radiation with a large dose of penetrating rays likewise represents an indirect effect. It has been interpreted as due to the autolytic solution of tissues under the influence of radiation (Edsall and Pemberton). Recently Hall and Whipple pointed out a similarity between the radiation-toxemia and the intoxication after parenteral ingestion of proteoses. These authors identify these two processes; as the result of the application of a large dose of penetrating roentgen rays they found intestinal changes which they hold responsible for the proteosis intoxication. However, in the roentgen-ray intoxication the coagulation of the blood is apparently accelerated, while in proteosis intoxication it is markedly delayed. These two processes are therefore in all probability not identical with each other.

17. Long-continued stimulating action of roentgen rays (and probably also of radium) on previously normal tissues may convert these tissues into cancerous tissue, carcinoma or sarcoma. This transformation represents, in all probability, another instance of the stimulating effect of radiation on the growth processes in tissues. It is as yet doubtful how much non-specific stimuli of a regenerative character are concerned in it. It is furthermore possible that an active immunization of the cells against radiation may convert otherwise injurious rays into stimulating ones, and thus contribute to the cancerous transformation.

THE PRESENT FIELD FOR THE USE OF THE X-RAYS AND RADIUM IN THE TREATMENT OF MALIGNANT NEOPLASMS*

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ROENTGEN rays and radium in the treatment of malignant neoplasms are still accepted reluctantly by the surgeon, except as palliative agents in the advanced stages of the disease. Their application before the patient is in an incurable stage appears to be an insufficiently tested method. In the case of *x*-rays, it is particularly so, for, before the recent advent of the high voltage machine, *x*-ray therapy had become so overshadowed by the results of radium that it had lost somewhat of its early reputation.

It seems, therefore, to be an opportune time to review this work, as it has been presented to the writer during a service of seven years at the Memorial Hospital. During this period more than 10,000 cases of neoplastic disease have been under his observation, to the majority of which *x*-rays or radium has been applied. We feel that we have now arrived at a position in this work from which we may discuss *the surviving old, the establisbed new,* and *the still experimental.*

As to the *surviving old,* the operation no longer maintains its former position of being the only method of treating cancer in the curable stage. It is no longer in many fields the method of choice. There still remain, however, numerous fields in which our enthusiasm for the physical agents must not allow the postponement of the operation to lessen or take away its chances of success. In all the well-advanced cases, and in those designated as being in the borderland of operability, in which formerly a radical operation was attended by a high primary mortality and a low percentage of cures, the surgeon's responsibility is not fulfilled until all the aid has been enlisted which *x*-rays and radium can supply. In fact, there are few, if any, early cases of malignant neoplasm, in which these agents do not merit consideration, if only as an adjunct to the operation. In other words, the surgeon's position as a technician has been made easier, but from the viewpoint of diagnosis and proper selection of cases, his responsibility has become greater. Even in diagnosis, the therapeutic test of irradiation will often render an exploratory operation unnecessary. Instead, therefore, of being supplanted by these agents, the field of applicability of the operation has been limited strictly to the earliest stages, by which, also, we may hope to define more accurately its curative value.

Of the *establisbed new,* we now have numerous facts relating to the conditions upon which the effects of irradiation depend. While the early observations have been confirmed, that tumor cells, in general, respond more promptly to the action of the *x*-ray and radium than the normal tissues, such wide variations are shown among the different types of tumors, even between tumors of the same type in different parts of the body, that we can hardly appreciate the basis for speaking of a carcinoma or a sarcoma dose. Just as wide variations also occur among the sarcomas as among the carcinomas.

The effects of irradiation depend upon the size, extent and condition of the tumor. The size, however, is of less importance than with the operation, some of the bulkiest of abdominal tumors, for example, disappearing within a few weeks. The extent of the tumor is also of less importance, but an extension to a neighboring bone, unless the tumor is of the most responsive type, will seriously interfere with the result.

The condition of the tumor and its neighboring tissues, next to its type, determines the success or failure of irradiation more than any other factor. Infected tumors respond unfavorably, and a syphi-

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litic base, in a lesion of the tongue, for example, invariably hinders the progress of the regression. A tumor also with altered nutrition, in which the general condition of the patient may still be apparently good, may soon become so necrotic from the irradiation that the terminal period of the disease is prematurely initiated. The fear of toxicity, however, from the absorption after irradiation of the products of disintegration in a normally nourished tumor has been, I believe, somewhat exaggerated in the literature. Fibrosis resulting from an operation or a previous irradiation makes a tumor less responsive. The greater effects of these agents upon tumors and normal tissues which have not been previously irradiated is universally accepted by all observers. The existence of normal neighboring tissues and their preservation by the avoidance of overdosage constitute an important factor in the process of cure. The killing of the cancer cell is only one of the essentials, to which must be added a proper amount of inflammatory reaction on the part of the stroma of the tumor and normal tissues. For this reason, also, a poor condition of the general health, altering the nutrition of the tissues about the tumor, makes conditions which are unfavorable for regression of the tumor.

The general health of the patient must be considered, also, because of the toxemia which necessarily results from the application of these agents—a subject which deserves more consideration, especially in the case of elderly people, than it has hitherto received. The effect of these agents upon the blood must also demand our attention. It is not improbable that the cell count may become an aid in determining the intervals between treatments. In observing the general condition of the health, it is necessary to distinguish between a condition resulting from hemorrhage or toxicity from a necrotic tumor, and the cachexia from the generalization of the growth. In the latter condition, any treatment is contraindicated, but in the other conditions a stoppage of the hemorrhage or the removal of a necrotic focus may enable irradiation subsequently to produce satisfactory results.

Much confusion exists regarding the relative merits of *x*-rays and radium, but so far as we are able to judge clinically, the effects of *x*-rays and the gamma rays of radium are the same. With a supply of 4 gm. of radium, however, we have been able to obtain more marked effects upon deeply situated tumors than we have from the use of the *x*-ray machines delivering not over 100,000 volts. The effects of each depend upon the power of absorption the tissues possess for rays of certain wave-length. Some of the gamma rays, we know, are of such short wave-length that they penetrate the tissues without being absorbed, and without, therefore, producing therapeutic effects. We hope, then, to obtain from the transformer producing a higher voltage a quantity of *x*-rays of sufficiently short wave-length to make this agent an efficient substitute for radium in cases in which deep effects are required. It will be an error, however, to undervalue the therapeutic effects that have already been obtained by the use of the lower voltage machines. Numerous cases do not require rays of shorter wave-length than these can produce, and with a technique in which distance, filtration and time are increased materially, we await improved results with the old machines.

A review of the material from which these general facts were obtained enables us to present numerous clinical fields in which, although the response to irradiation varies widely, the results indicate that *x*-rays and radium have a specific field of applicability.

Lymphosarcoma, metastatic teratoid tumors of the testicle, certain embryonal tumors of the kidney in children and a type of bone sarcoma recently described by Ewing as endothelial myeloma, represent types of neoplasm which promptly respond either to the gamma rays of radium or *x*-rays after a single application. The unfortunate results of biopsy or operation in lymphosarcoma may be avoided by the therapeutic test in cases of a doubtful nature. The metastatic teratoid tumors of the testicle are even more responsive than lymphosarcoma, but we are not yet prepared to offer definite conclusions regarding the treatment of the

primary tumor. For the present, we think it should be excised after a preliminary irradiation. We have observed only a few embryonal kidney tumors in children, but in each case the regression has been favorable. The endothelial myeloma may be best discussed with the other bone tumors, but the response to irradiation is so similar to lymphosarcoma that they are included in this group.

There are other tumors in which the response to these agents is often prompt, but the results vary. *Mixed tumors* of the *parotid*, depending upon their individual structure, vary widely, but on account of the nerve palsy and deformity that so often follow the operation, a preliminary trial of irradiation should always be made.

The results in basal cell epithelioma, or rodent ulcer, discovered by the pioneers in *x*-rays to be susceptible to that agent, have been so greatly improved by radium that operation is rarely indicated. Errors in diagnosis, however, are easily made, and the condition of the growth has been so often altered by unsuitable previous treatment that it may be wise to give a guarded prognosis. In lesions near the eye, in which ectropion so invariably follows the operation, the superiority of radium is well shown.

There is a large field of ulcerating growths of the skin and mucous membranes, in which, by the additional use of the beta rays and by implantation of radium into the tumor tissues, results have been achieved in many instances beyond those that have hitherto been accomplished by the knife or cautery. In this way, during the past three years, lesions of the lip, tongue, mouth, tonsil, larynx, etc., have been brought into a group in which the operation has been supplanted, practically, by the use of radium. This use of radium, however, is taking advantage to some extent of its caustic qualities, concerning the action of which there remains much to be investigated. In all these lesions, especially of the lip and tongue, the regional invasion of the lymph-nodes presents the most difficult part of the problem, for the solution of which a judicious combination of surgery and these agents is required. For the performance of this work considerable experience in their use, and radium in a suitable form, are necessary, so that the choice of procedure may depend upon the amount of experience in the use of these agents that the patient is able to command.

In uterine cancer, radium has achieved its most brilliant success as a curative agent, especially in lesions of the cervix, in which surgery has now a very limited field, if any, of applicability. The results of surgery, however, in early lesions of the uterine body are so good that, for the present, at least, operation after a preliminary use of radium appears to be the method of choice. A most conservative statement would be that any uterine lesion requiring more than a simple hysterectomy for its cure should be treated by radium. Our experience with the *x*-ray does not justify our reliance upon this agent alone in the treatment of uterine cancer. Even in Germany, there have been only a few cases, I believe, in which radium has not been used in connection with *x*-rays.

The results in all the other growths of the mucous membranes fall short of those we have just discussed. There is little evidence of practical accomplishment in cancer of the esophagus and stomach. Our primary results in tumors of the bladder, because of the frequency of their papillary and non-infiltrating character, justify the expectation that these agents will have definite curative value. There is already no doubt of the palliative value of radium. There is also much evidence of its palliative value in cancer of the prostate, but special care is needed in the selection of cases, because the treatment temporarily adds to the patient's discomfort, and the prolongation of life must, therefore, be sufficient to justify the attempt.

Cancer of the rectum has proved a more difficult problem than our first results led us to expect. The extreme sensitiveness of the normal mucosa makes it difficult to give a sufficient dosage, and in an annular growth a permanent stricture is practically impossible to prevent. Life in such instances may be prolonged, but it is usually at the expense of suffering. In any serious effort to cure this lesion by irradiation a preliminary colostomy is necessary. Annu-

lar lesions, to be suitable for radium treatment, must be practically of the same early type in which the operation is indicated. In lesions limited to part of the circumference of the rectal wall, surface irradiation combined with the implantation of radium in the growth, and followed subsequently by excision, has produced better results than could be obtained by the operation alone. Cessation of bleeding and pain in a few advanced lesions have been accomplished by the use of the gamma rays. It may be that *x*-rays will accomplish much better results.

There is little need of discussing the applicability of these agents to inoperable and recurrent lesions, except to direct attention to the abuses, which the circumstances surrounding the patients in these stages of the disease so often lead us to practice. It is surprising how long an interval will elapse before a patient with a recurrence is referred to a radiologist, whereas there is the same necessity of treatment in the early stage as there is in the case of the primary growth. Neither agent is applicable for the terminal period of the disease. It too often happens that, instead of receiving morphine and good nursing care, the patient is dragged about in the forlorn hope of being helped by *x*-rays or radium. Both the surgeon and radiologist are responsible for these abuses. The surgeon, whose enthusiasm for the use of irradiation may only begin when he sees the opportunity of avoiding a disagreeable situation, too often emphasizes its value then, and the radiologist is able only to carry out what he knows to be a hopeless undertaking. The performance of an incomplete operation before the case is referred to a radiologist is fortunately becoming less frequent. In New York, we have seen this most frequently in the case of uterine cancer, in which the removal of the uterus materially lessens the value of irradiation. However, in the proper selection of cases, some of the most advanced growths have yielded to irradiation in a remarkable way. As with the primary tumor, success depends upon the type, size, extent and condition of the growth. Regarding metastases, the writer has been fortunate in observing favorable results following the application of the gamma rays of radium to bone metastases from mammary cancer. There appears to be more than an even chance of relieving pain, and in a few instances, the repair of the lesion, as shown in the roentgenograms, and a temporary restoration of the general health have justified our efforts.

Of the *still experimental*, it may fairly be said that all this work is experimental, because, even in the fields where much has been established there is much more awaiting both laboratory and clinical research. There are a few clinical problems, however, in which we are now especially interested.

The prophylactic use of irradiation before and after operation is, perhaps, one of the most important, and cancer of the breast, although much has already been established regarding the irradiation of this tumor in its advanced stage, presents a profitable field for the discussion of this subject. Growths of these organs vary widely in their nature and in their response to irradiation. We have observed that a few primary tumors apparently disappear after the application of *x*-rays and radium. A partial regression has been observed in a large number, and after repeated applications they have shrunk to an inactive lump. We have also seen tumors inoperable because of their extent and fixation become transformed into tumors that were apparently operable. As our technique has improved, and radium has been implanted in the tumor tissues, much better results have been observed, so that a few cases, in which for special reasons the operation was contraindicated, we have trusted to irradiation alone. From such observations we must conclude to make use of these agents in conjunction with the operation during the early stages of the growth.

The postoperative application is becoming a routine procedure, and it is reasonable to believe that an increased number of permanent cures will result. We do not yet know, however, how soon after the operation to begin the treatment, how often to apply it, how long it should be continued, or what dosage to apply. We have assumed that it will do no harm. Recurrences take place in spite of this treatment, and, accord-

ing to the writer's experience with irradiation of Hodgkin's disease, nodes, which appear in areas that have been prophylactically irradiated do not respond as promptly as those occurring in areas that have not been previously treated. In Hodgkin's disease, also, after irradiation over long periods, injurious effects have been demonstrated at the autopsy table, on normal structures. In a case of mammary cancer, one year after operation, in which a few supraclavicular nodes had been the only evidence of the disease for several months, one application of *x*-rays to the chest wall and neck was followed in ten days by a rapidly fatal recurrence in the chest wall and pleura. While such observations do not condemn the procedure, the necessity is suggested for closer study of the effects of these agents upon normal tissues.

The pre-operative treatment of mammary cancer is much less popular, but it appears to the writer to rest upon a more scientific basis than the postoperative application. From our own observations we must believe that the injurious effects of the operation are thereby minimized. Numerous objections, however, to this procedure are offered by the surgeon, a few of which deserve our discussion. The objection that the healing of the wound is delayed, is based apparently upon a few scattered observations. On the contrary, a prominent surgeon recently stated that after irradiation he observed that wounds healed better and left a better scar. A greater liability to wound infection appears to have some basis of fact. The writer has made several observations of a peculiar erysipeloid skin infection, occurring several weeks after treatment in the presence of an open wound, which suggests a relationship to the previous irradiation. The objection that the operation is made more difficult is the one most frequently offered, but, in the case of the breast, except for a slightly increased tendency to hemorrhage, if performed too soon, it is difficult to conceive that such an objection is valid. It is most often observed in connection with the performance of a hysterectomy for uterine cancer. It is usually based in this field upon an erroneous conception of the extent of the lesion before treatment. If there has been little or no extra-uterine tumor tissue, there will be no hard tissue to cut through. If, however, as a result of the irradiation, a considerable amount of extra-uterine tumor tissue has been converted into a fibrotic scar, the operation will naturally be difficult. A correct conception, however, of the original lesion would have shown that the operation was contraindicated. The general adoption of preoperative treatment in mammary cancer will soon show, I believe, that the fleld of applicability of the radical operation should be much restricted. It already seems to the writer that the presence of hard, fixed nodes in the apex of the axilla makes the cases as unsuitable for a radical operation as does the presence of supraclavicular nodes. It is a question how long it will be before the *radical* operation in mammary cancer will be entirely discarded.

The use of the *x*-ray and radium in the treatment of primary bone sarcoma is in the experimental stage, but a few facts have been definitely established, and our results suggest that, with greater accuracy of diagnosis, with an improved technique, and with more frequent resort to the use of these agents prior to operative procedures, more substantial progress will be made. First, our work has confirmed the experimental results of the physical laboratory which show that the bone structures offer but little more resistance to the penetration of the rays of these agents than the soft tissues. The most substantial evidence of this is seen, in addition to the clinical improvement, in new bone production as demonstrated in the roentgenograms. As in the soft tissues, we have found that the effects depend upon the nature, size, extent and condition of the tumor. Infection and necrosis from overdosage are greater obstacles to success in bone tumors than in tumors of the soft parts. Bone tumors that responded well at first did badly after they had become infected. The type of the tumor is the most important factor.

In the malignant osteogenic tumors, which were most often of the periosteal type, our clinical results were practically negligible, except in one or two instances. In numerous cases, however, the evidence

of new bone production, although often slight and temporary, in the roentgenograms showed that effects had been produced; and it leads us to hope that, by irradiating such tumors prior to amputation, the final results will prove to be better than they were when the operation was the only resource.

In the giant-cell tumors, or relatively benign giant-cell sarcoma, varying in type from those which closely resemble the osteitis fibrosa or bone cyst, to those in which their local extension and recurrence show considerably malignant qualities, our progress has been both encouraging and disappointing. Radium has been applied to the wound after curettage to prevent recurrence, and in numerous instances, the local recurrences after the operation, either by surface irradiation or by implantation into the tumor, have completely disappeared. Necrosis and infection, however, have often made the progress of repair slow, and, in a few cases, failure of the wound to heal, although the growth had been stopped, made amputation finally necessary. The results of the use of *x*-rays or the gamma rays of radium in tumors of this type, which were inoperable on account of their location, lead us to think that, with their earlier recognition by means of the clinical history and *x*-rays, this form of therapy may ultimately prove to be an efficient substitute for incision and curettage.

In the progress of this work a tumor presenting many of the features clinically of a malignant periosteal sarcoma responded primarily to irradiation by the gamma rays of radium as promptly as lymphosarcoma. A similar response occurred in several other cases of bone tumor, all of which showed the same histological features, and which Ewing has described as endothelial myeloma. Although they differ from the characteristic features of each of these tumors, histologically and clinically they resemble both. From the *x*-ray standpoint they resemble giant-cell sarcoma and myeloma, but differ from each. In the long bones they begin in the shaft. Clinically, they occur in youth, are often multiple when first observed, and in general, present the picture of a malignant tumor. They are usually described as round cell sarcoma of the bone. If, like myeloma, they have a multiple focus of origin, we may expect nothing more than a palliative result, which we obtain by the use of irradiation in that disease.

In conclusion, in addition to supplanting the operation as the method of choice in a number of fields of malignant neoplasm, the use of irradiation has so limited the field of applicability of the *radical* operation in numerous others that it is becoming a questionable procedure. In uterine cancer, it is entirely eliminated, and, in mammary cancer, it is a question of accurate diagnosis.

The use of irradiation, therefore, has made greater refinement in diagnosis necessary.

To this end, the patient's interests are best conserved by obtaining the conjoined knowledge of the surgeon and radiologist. In fact, cancer therapy has become an institutional problem requiring more clinical experience and knowledge of surgical pathology to use physical agents than does the operation.

ANTE-OPERATIVE RADIATION OF CARCINOMA OF THE BREAST*

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A SUFFICIENT number of cases of carcinoma of the breast have received ante-operative radiation with such favorable results as to justify advocating preraying of every case of cancer of the breast, regardless of the stage of the disease. By so doing, more lives will be saved and a greater amount of suffering will be obviated. The surgeon will then be operating on a breast the greater part of whose cancer tissue has been destroyed by radiation, and the remaining cells will be in a latent condition. The lymphatic channels, instead of being wide open, will be partly blocked and there will not be the same danger of metastases.

It is surprising that surgeons have not before now realized the value of ante-operative radiation, especially since the fact is well known that even in the early cases, when the axilla is free microscopically, there is a recurrence in about 20 per cent of the cases, and that when the axilla contains cancer, microscopically, only about 20 per cent are cured by surgery alone.

It is a question in cases of well-established cancer of the breast whether anything besides removal of the breast should be performed, depending upon radium and *x*-rays to cause retrogression of cancer cells in the adjacent lymphatics. After radiation, the glands in the axilla which are palpably enlarged can frequently be obliterated, and when they are removed and examined often contain very few or no cancer cells. Therefore, as a routine procedure, ante-operative radiation should be given in every case, and since such pronounced results have been obtained in advanced cases, every early case should certainly be included in the attempt to lessen the danger of metastases at operation.

In estimating the value of ante-operative raying, it is necessary to determine the structural type of cancer under treatment. The prognosis is different in schirrhus, adeno- or medullary carcinoma, and also depends on whether the growth is circumscribed or infiltrated. The stage of the disease and the extent of the metastases must be taken into consideration before we can decide whether a cure should be expected or whether palliation with retardation is all that can be hoped for. Better results will naturally be obtained when the tumor is localized in the breast than when the axillary glands contain cancer cells, and better results will be obtained in cases in which the cancer cells can be found in the axilla microscopically than when the axillary nodes are palpable. When there is a well-established cancer of the breast, with general metastases, any kind of an operation, unless it is preceded by radiation, always hastens the progress of the disease and may increase the patient's suffering.

The present operation, however perfect it may seem, always shortens the patient's life, and never affords any palliation in such advanced cases. An operation at this stage is followed, in almost every instance, by a local recurrence, edema of the arm with unbearable pain, and rapid spread of internal metastases. The patient's condition is made so much worse that there is not the same response to radium and *x*-rays as in cases which have not been operated upon. It is generally true, that recurrence and metastases do not respond as readily as primary carcinoma. In some cases, at least, an incomplete operation transforms a slowly growing carcinoma into one of much greater malignancy. During the past few years, postoperative radiation has been so popularized that the public is demanding it; and the surgeon is always willing to let the radiologist share the responsibility of the recurrence. In the past, surgeons as well as radiologists believed that, after the bulk of the cancer had been removed by operation, the

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remaining cancer cells could be eradicated by radiation; but with the increasing number of cases we treat postoperatively, the lesson taught us is that this is a difficult task even when the best technique is used in both radium and deep *x*-ray therapy. It seems safe to estimate that in over 20 per cent of the cases which are being operated upon today, cancer cells cannot be totally eradicated surgically. This alone is sufficient reason for advocating ante-operative treatment at the time when the radiation gives the most favorable results.

Groover, Christie and Merritt advocated ante-operative raying in the following words: "Personally, we are of the opinion that this large group is in a worse condition than before operation. To state the case more succinctly, we believe that for every cancer of the breast cured by surgery alone, 4 have been made definitely worse. We are rather strongly convinced that they are worse, not only from the standpoint of the patient's actual condition, but also from the standpoint of any anticipated benefit from radiotherapy. It has already been intimated that it has been our experience that recurrences of breast cancer respond much less favorably to radiotherapy than do primary growths. This is true of cancers in general, and is particularly notable in cancers of the uterine cervix. In cases referred for postoperative radiotherapy, while it is true that we are not called upon to treat a recurrence, we are called upon to treat a traumatized cancer, and the analogy is not as far-fetched as might appear at first thought."

Sittenfield[1] states: "It has been shown experimentally that radiated cancer cells do not grow on transplantation. This has been taken advantage of by the surgeons, reducing to a minimum the risk of transplanting cancer cells during the surgical removal of carcinoma of the breast."

Quick[2] concludes his paper as follows: "Finally, we wish to point out certain theoretical considerations which strongly encourage us to pursue the study of the treatment of mammary cancer by radium and *x*-rays. When one embeds radium emanation needles in a primary tumor and in invaded lymph-nodes and follows with massive *x*-ray dosage through the skin, a powerful destructive effect is produced on the tumor tissue amounting to local necrosis; the lymphatics may reasonably be considered sealed, invisible vagrant cells are incarcerated or destroyed, and all this is accomplished without removing the natural barriers which exist against progressive carcinoma. In fact, both types of radiation tend to increase the exudation of lymphocytes and plasma cells and the growth of connective tissue around the tumor, and these are the only natural agents of resistance to carcinoma that we know anything about. The treatment of mammary cancer by these physical agents is, therefore, based on sound theory, since it intensifies the natural reaction of the tissues to carcinoma, while producing in addition a very strong destructive action on the tumor cells."

Holmes[3] concludes by saying: "Recently we have had a small group of cases of carcinoma of the breast in which there was evidence of metastasis, glands being palpable in the axilla and above the clavicle. For this or other reasons they were not operated on, but were subjected to *x*-ray treatment alone. These cases have certainly done much better than similar cases operated upon and followed by radiation. I cannot but feel that the operation in some way breaks down the natural resistance of the patient, and interferes with the walling-off process which is the result of connective-tissue stimulation."

Hernaman-Johnson[4] advocates pre-operative raying, as follows: "In the opinion of many competent to judge, it has been experimentally proved that *x*-rays in suitable doses raise the immunity of the body to cancerous invasions. Radiotherapy should, therefore, be administered before operative removal. Such pre-operative treatment has the dual advantage of depressing the cancer cells locally before any surgical trauma has disturbed them, and, at the same time, increasing the general powers of resistance to any subsequent migration. In view of what Sampson Handley has shown as to the radiating growth of cancer along the lymphatics, it is obvious that local treatment should embrace a very wide area."

Pfahler[5] states: "It has been shown that thorough radiation treatment of cancer tissue will devitalize the cancer cells so as to interfere with their inoculation or further development. This justifies our recommendation of ante-operative treatment."

The work accomplished by these authorities as well as other radiologists has been the means of inducing surgeons to advise ante-operative radiation. Surgeons who have made an extensive study of carcinoma of the breast admit that even with their perfect technique, all cancer cells cannot be removed by the most thorough dissection, except in early cases. They are now looking to the radiologist for the best method of radiation, and it is incumbent upon us to advocate ante-operative radiation.

The treatment of carcinoma of the breast by imbedding radium throughout the breast and the adjacent glands, *preceded* by surface applications of radium and heavy filtered *x*-rays, makes radiation as thorough as amputation with the most careful glandular dissection. After such radiation, removal of the breast may be indicated, but a radical operation may not be necessary.

The reason for advocating radium by the method described is that early cases can be clinically cured without opening the lymphatic channels, and, if operation is indicated later, it is performed when the cancer cells are nearly all destroyed; that is, when cell proliferation is checked and only latent cancer cells are removed. In some cases, imbedding radium would at least take the place of operation, but until we have more data, it seems advisable to operate between three and eight weeks after radiation, depending upon the case. In late cases, radiation as just described is certainly superior to any form of operation primarily, and, if the breast is removed, the axilla should rarely, if ever, be opened following the radiation.

The lethal dose has created much discussion, and the radiologist's success depends upon his ability to give this dose without producing superficial ulceration or necrosis. For most types of cancer of the breast, the erythema dose is seldom the lethal dose. In my opinion the lethal dose may sometimes be from three to six times the erythema dose. This is why I imbed radium in carcinoma of the breast, in addition to giving deep therapy through the skin surface. By imbedding needles, very much more radiation can be given without serious injury to the uninvolved tissue. It is to be remembered that implantation of radium, if sufficiently deep, in no way interferes with applying full doses of deep *x*-ray over the surface. *X*-rays are always applied as thoroughly as though no radium had been imbedded.

The Germans, and a few American radiologists, believe that less than an erythema dose is a lethal or cancer dose. I am sure this is not true of all types of breast cancers. I still believe we must follow, to a certain extent, the older method of crossfiring, even with the best combination of the above factors, and give more than an erythema dose to certain glandular areas in which metastases are prone to occur, especially when radium cannot be imbedded.

No uniform technique has been established in deep *x*-ray therapy. At present it is applied by the use of a transformer, backing up a spark varying from 9 to 20 in., and the filtration employed is from 3 to 10 or 20 mm. of aluminum or its equivalent in copper or zinc. Some radiologists use only two ports of entry while others use smaller ports and crossfire as much as possible. It can be seen that the opinions of radiologists greatly differ. Some believe that as much radiation can be delivered by the use of a 9 in. back-up as by considerably higher voltage, provided sufficient length of time is employed, while others claim that there is some difference in the quality of radiation when the higher voltage is used. There is some confusion in regard to the size of the ports of entry. A deep erythema dose can be given by the 10 in. transformer, provided a sufficient length of time is employed, and, on the other hand, there is no question that the higher voltage machine has come to stay. Every one using deep *x*-ray therapy should work with a physicist and know the amount of radiation received in every centimeter of tissue beneath the

skin from the anterior to the posterior surfaces.

The only practical method by which the radiologist may estimate the *x*-ray dosage is to determine the skin erythema with sphere gap voltage, milliampèrage, skin target distance and filtration, together with measurements of the patient. Then by tables of dosage he must decide upon the size and number of ports of entry. By increasing the size of the port of entry, the secondary and scattered radiation increase the depth dose. Many have been led to believe that they should use the largest port of entry possible in order to secure a greater ratio of secondary and scattered radiation; but this is not entirely true. In a great many instances it is much better to increase the number of ports of entry, because the radiation can thus be better directed to the glands in which metastasis has occurred. According to Friedrich, there is a greater increase in scattered and secondary radiation when the size of the port of entry is increased from 5 × 5 cm. to 10 × 10 cm. than when increasing its size from 10 × 10 cm. to 15 × 15 cm. The percentage effect of scattered and secondary rays is greater at a depth of 10 than at 5 cm. In filtering through 10 mm. of aluminum, at a depth of 10 cm. from the surface, using a 5 × 5 cm. port of entry, the depth dose is .22; by using a 10 × 10 cm. port of entry, the depth dose is .27, and by using a 15 × 15 cm. the depth dose is .31. This shows that increasing the size of the port of entry, when you calculate it in square centimeters, is much greater between 5 cm. and 10 cm. than between 10 cm. and 15 cm. Using two ports of entry, 10 × 10 cm. would include 200 sq. cm. of skin exposed to radiation. The depth effect from the two 10 × 10 cm. portals gives 2 × .27, or .54, while the depth effect from the single 15 × 15 cm. portal (225 sq. cm.) is only .31. Hence, for about the same skin area involved with two smaller portal areas (10 × 10) the depth effect is $\frac{54}{31}$ or 74 per cent greater effect than through the one larger skin portal (15 × 15). When the dosage has once been obtained, this is only true with the same *x*-ray apparatus working exactly under the same conditions. It cannot be transferred to other makes of apparatus by any process of arithmetic. Therefore, the dosage must be checked for different transformers.

I have not adopted the German technique of one or two large areas in the treatment of carcinoma of the breast, because there are 20 or more chains of lymphatics connected with the mammary gland. Each one should have the most efficient radiation possible. The same depth dose could not be given by one or two large ports of entry to all the lymphatic chains which are likely to metastasize as is given by the following ante-operative technique, using over 20 ports of entry, including almost the entire skin area of the whole chest. This outline of treatment is a general one, subject to modifications; but in all cases the utmost care must be taken to direct the radiation through each port of entry directly towards the main glandular junctions. The outline of my technique is as follows:

The breast is divided into four areas:

5th area, in axilla (or radium packs).

6th area, 4 in. square, above the breast, extends to the clavicle above, and on the inner side from a line drawn through the sterno-clavicular junction.

7th area, 2 to 3 in. square, to the outer side of the above area, treatment directed through the axilla.

8th area, 2 × 4 in., above the clavicle.

9th area, 4 × 4 in., over the scapular region, adjoining the supraclavicular area.

10th area, 4 × 4 in., subscapular, directed upwards through the mediastinum.

11th area, 3 × 4 in., external to scapular area directed through the axilla.

12th area, 4 × 4 in., below the above area, directed upwards through the axilla.

13th area, 4 × 4 in., internal to scapular area, directed through mediastinum.

14th area, 4 × 4 in., internal to subscapular area, directed upwards through the mediastinum.

15th area, 4 × 4 in., internal to 6th area, directed through the sternum to the mediastinum.

16th area, 4 × 4 in. below this area, directed through the mediastinum.

The series is completed by taking areas of similar size through the opposite shoulder, axilla, supraclavicular and scapular areas, and if the tumor is situated

on the inner side of the breast, the opposite breast should never be omitted. An area is given over the pit of the stomach and also through the liver, in all advanced cases.

The *x*-ray dosage I have adopted is the following: filter of 10 mm. of aluminum; 8 in. target skin distance; 5 milliampères of current; 9 in. spark back-up, and from twenty to thirty minutes' exposure. The most important factor is a constant voltage passing through the tube. This is extremely difficult to maintain and requires constant attention during the treatment. Thirty minutes are given over the breast, axillary, clavicular and supraclavicular areas, and in most instances twenty minutes is given to each of the other areas. The axilla on the affected side is usually treated by a radium pack 6 × 6 cm., placed at a distance of 2 cm., the radium being filtered through ½ mm. of silver and 1 mm. of brass, giving from 1,000 to 1,200 mg. hrs. Two to four weeks after the surface radiation, where cell proliferation has been checked, 10 mgm. radium needles are imbedded, placing them about 1 cm. apart, usually using 35 or more needles and giving from five to ten hours' exposure. Unless these needles are completely inserted, a necrosis on the skin will be produced. Radium so imbedded has more effect on the cancerous tissue than any form of surface application, not only because it can be placed in the center of the growth, but because the subcutaneous tissues will tolerate at least from three to five times as much as the skin without producing necrosis. Therefore, 350 mgm. of radium imbedded in 35 needles will have the same effect on the cancer cells as 1½ gm. placed on the surface.

In the *x*-ray treatment, usually from two to four ports of entry are given each day, and to include the number of fields described usually requires between one and two weeks. I have found that most patients will tolerate this amount of radiation without suffering to any great extent from radiation sickness. Besides, I believe it matters very little whether the radiation is given all in one day or within a week or ten days. At the Memorial Hospital I found that the results produced by imbedding small emanation seeds were identical with those we are producing by radium needles. The radium emanation seeds are quite active for a period of nearly two weeks, while the radium needles are left in place from five to ten hours. I believe the same holds true in giving deep *x*-ray therapy, whether the areas are all treated in one day or in a week or ten days. The *x*-ray technique mentioned above has been carried out with the 10 in. transformer. I am about to install a high voltage machine; hence, I am unable to state from personal experience how much advantage will be gained, but I feel certain it is a step in advance.

During the past two and one-half years, following the surface applications, I have been imbedding radium in the breast, in the glands leading to the axilla, in the axilla and in the glands beneath the clavicle; but the present time limit prevents going into details regarding the number of cases operated upon except to refer to the clinical results. In most of the advanced cases, the disease in the breast and in the glands has clinically retrogressed. Of course, in some cases, there still is thickening due to fibrosis from the radiation. In the inoperable cases we were usually inclined to leave well enough alone, and the early cases treated had in most instances refused operation. My advice has been, even in the advanced cases in which the disease has clinically receded, to have the breast removed after radiation without opening the axilla. In every instance in advanced cases in which the axilla was opened, the operation was harmful, because the patient would usually return with a swollen arm and in a much worse condition than before the operation. The few cases in which the breast only was removed seemed to be benefited by the operation.

In this connection, report of the following case is especially interesting:

Female, aged seventy, was referred with inoperable carcinoma of the breast. There was a mass about the size of a hen's egg in the upper third of the breast with a more or less diffuse infiltration throughout the entire breast. The skin was adherent to the mass, and there was retraction of the nipple, and marked axillary involvement, one

gland being as large as a hickory nut. A thorough course of surface radiation was given, followed by implantation of 350 mg. of radium into the breast, into the glands leading to the axilla, into the axilla and beneath the clavicle. After the radiation, the growth in the upper part of the breast was reduced to a fibrous mass and the axillary glands were scarcely palpable. The breast was then enucleated by Dr. J. W. Robinson.

The following is the pathological report of Dr. DeWayne Richey, who made sections of the entire breast:

"Sections of the tissue from the breast showed vast expanses of dense, particularly acellular, pink hyaline fibrous connective tissue, scattered throughout which were eosinophiles, lymphocytes and plasma cells. At one end was a non-encapsulated mass of the epithelial tumor cells. These masses were solid in nature and were supported by heavy fibrous bands. Many of the tumor cells occurred singly, being separated from each other by the fibrous stroma. In these instances the cells were small and shrunken and the nuclei were pyknotic. The larger tumor cell masses were made up of polygonal cells with round, vesicular nuclei. Mitotic figures were not frequently observed. There were no areas of necrosis. The tumor cell masses were decidedly invasive in character. The small size of the cells and the extensive fibrosis suggested probable results of radium and *x*-ray therapy."

If the above results can be accomplished in a case so far advanced, there is obvious justification for treating all cases anteoperatively in both early and late stages.

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THE DOSAGE AND TECHNIQUE IN THE X-RAY TREATMENT OF GOITER, TUBERCULOUS GLANDS OF THE NECK, TONSILS AND ADENOIDS*

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BEFORE proceeding with the description of dosage and technique it might be interesting to note some of the more recent contributions and clinical evidence of the association of these diseases with pulmonary tuberculosis.

Van Zwaluwenburg and Grabfield have published a study of a shadow representing a thickening of the pleura over the apex of the lung and its relation to tonsillar and cervical gland tuberculosis. This shadow is said to be present in 10 per cent of all roentgen-ray examinations: occurring in 93 per cent of all cases showing tuberculous deposits in the faucial tonsils, and in 59 per cent of cervical gland tuberculosis. It is suggested that the common route of infection may lie through the tonsil and cervical lymphatics to the apical pleura and thence into the lung. This hypothesis furnishes a satisfactory explanation for the frequency of apical lesions, the preponderance of right-sided lesions, of the pathogenesis of tuberculous pleurisy with effusion and other obscure features of this infection.

Janowski found symptoms suggesting exophthalmic goiter in 17 per cent of the 3,000 cases of pulmonary tuberculosis examined. In 10 per cent the symptoms of hyperthyroidism preceded the onset of tuberculosis from a few months to two years. In another 10 per cent the tuberculous lesions in the lung had long persisted in a latent phase until the onset of excessive thyroid function, and this had evidently accelerated the pulmonary process. He therefore concludes that in every suspected case of tuberculosis the thyroid should be investigated, and, in every case of hyperthyroidism, the lungs. Many of these patients are treated for hysteria, neurasthenia, or heart disease according as one symptom predominates.

Within the last few months we have seen one case of toxic goiter follow immediately an attack of follicular tonsillitis. In this case all the cardinal symptoms were present.

Blodgett, of Philadelphia, in a recent article reports 4 cases of diabetes of the acute pancreatic form due to an infection of the pancreas following an infection of the tonsil. In one case, acute pancreatic diabetes developed twelve days after severe infection of the tonsils. The appearance of sugar and lowered carbohydrate tolerance followed each of the three attacks of sore throat until finally death occurred.

The factors used in the treatment of tonsils and adenoids are as follows:

Seven in. spark gap, 5 ma., 10 in. distance, four minutes' time, filtered through 3 mm. of aluminum. This exposure is given at two-week-intervals, the number of exposures depending entirely on the progress of the case. So far, our experience has been that the average case requires from six to eight treatments, but to say that all cases require a fixed number of treatments is about as rational as advocating a fixed number of units for all cases of diphtheria. Careful observation and examination of the throat during treatment are as essential as the factors of the technique. On account of the sensitiveness of the skin, the dosage in children should be reduced proportionately according to the age.

The position of the patient is illustrated in Figure 1, with the target of the *x*-ray tube centered just behind the angle of the jaw, and the opening in the lead-foil extending over an area 2 inches wide from just above the external auditory meatus down to the hyoid bone.

In the treatment of goiter the same factors are used with an area of exposure extending from just above the external

* Read at the Twenty-Second Annual Meeting of THE AMERICAN ROENTGEN RAY SOCIETY, Washington, D. C., September 27–30, 1921.

auditory meatus down to the lower level of the thyroid gland and transversely to the center of the middle lobe. As in the treatment of tonsils, each side is exposed for four minutes, thus giving crossfire treatment to the gland and at the same time including the tonsils and adenoids. An examination of the throat in these cases of exophthalmic goiter almost invariably reveals chronic infection of the mucous membrane and tonsils. It is therefore essential that the infected tonsil and mucous membrane should be included in the area exposed in order to rid the patient of an infection which may be indirectly the cause of the toxic symptoms. The number of treatments varies in these cases and is regulated by the basal metabolism determinations.

The same dosage and technique may be used in the treatment of tuberculous glands of the neck. The area of exposure includes not only the tuberculous glands but also the tonsils and adenoids, for the reason that it is more than probable that the primary focus of infection is, or was, in the tonsil. The *x*-ray effect on the follicles and crypts of the infratonsillar nodule and the follicles throughout the mucous membrane of the pharynx is similar to that produced on the tonsillar tissue, namely, atrophy due to the destruction or absorption of the

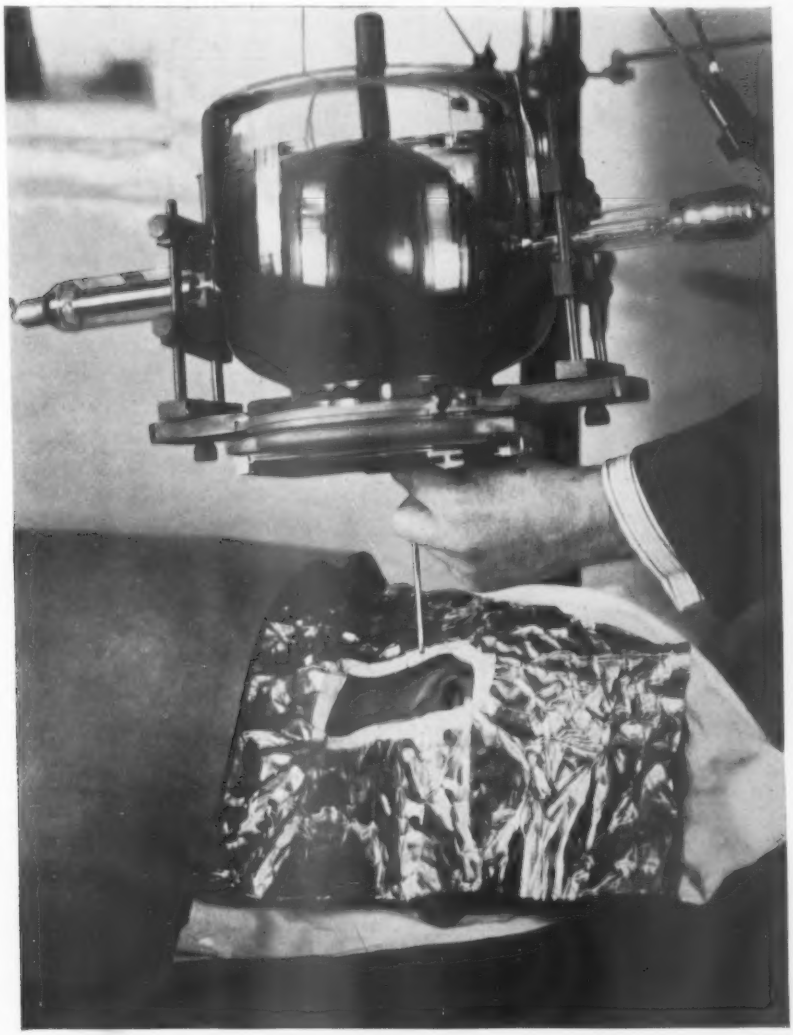

FIG. 1.

immature lymphatic cells in the follicles, thus lessening the depth and distortion of the crypt and at the same time causing an eversion and evacuation of its contents. In 30 out of 36 cases, hemolytic streptococci and staphylococci were eliminated from the crypts four weeks after one massive dose of *x*-ray.

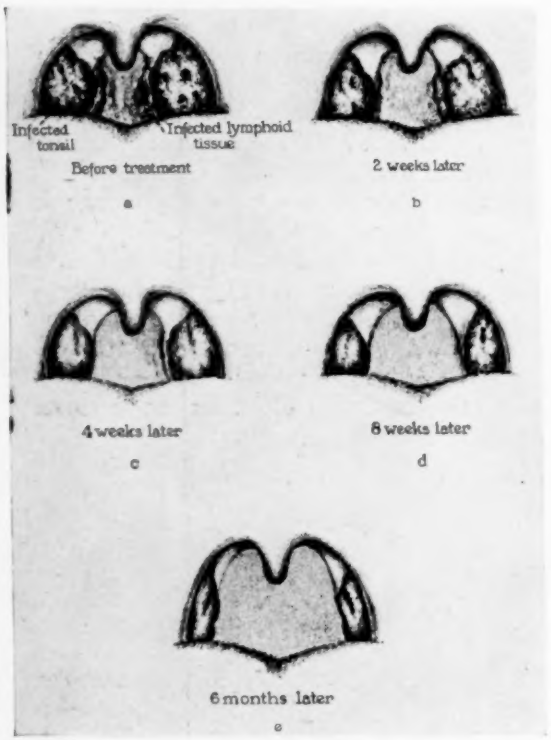

FIG. 2.

Investigations of a large number of cases of tubercular glands of the neck treated by *x*-ray prove not only that the treatment is harmless but also that the tonsil and adenoids and follicles of the mucous membrane have remained atrophied. In some instances three years have elapsed since the last *x*-ray treatment; in the more severe infections of the glands of the neck it has been necessary to give as many as forty treatments. This has been done without the slightest indication of any sign or symptom of the impairment of the functions of the normal thyroid, parathyroid, pituitary, and parotid gland. *X*-ray treatment of tubercular glands of the neck has been successfully carried out for the last ten years and a review of the literature on this subject does not, so far as I am aware, reveal a report of any case in which untoward effects have been recorded. The possibility of an *x*-ray burn is even more remote than injury to the adjacent glands, provided the technique is properly carried out.

In these chronically infected throats associated with exophthalmic goiter and tubercular glands of the neck, the infratonsillar nodule and lymphatics in the lateral and posterior walls may be markedly hypertrophied and contain numerous infected crypts. The operation of dissecting out these individual crypts after surgical removal of the tonsil and adenoids has proven inadequate is, necessarily, tedious and impractical from the standpoint of complete removal, although some cases of rheumatism have been temporarily relieved and benefited by this procedure. It is, therefore, essential in the treatment of goiter and tubercular glands of the neck that the tonsillar area be exposed, even though the adenoids and tonsils have previously been removed.

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CAPUT PUDDLING

BY ANTHONY BASSLER, M.D., AND J. RAYMOND LUTZ, M.D.

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LITERATURE exists on cecal stasis, little of it being presented under that entity; most of it is bound up in the large subject of intestinal stasis, or that of the colon. This literature is some years old, much of it was offered by surgeons to advance surgical therapy, and but little that is worth while has come from the internists. Perhaps the best single article is that of Behan's* which draws attention to adventitious bands in connection with stasis of the cecum and chronic appendicitis, presenting the operative side of the subject.

FIG. 1. The left half of the colon and all of the transverse colon are empty of barium, puddling in the caput cecum being marked.

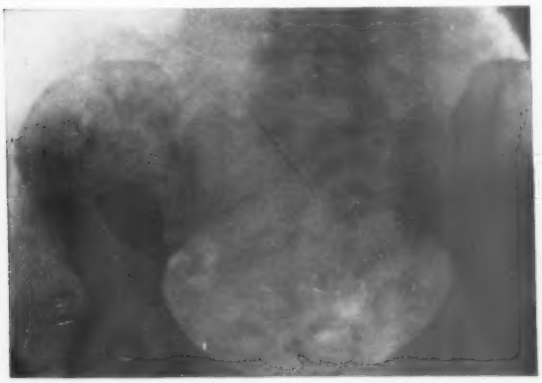

FIG. 2. In some cases there is some residue in the ascending colon, this being sparse and scattered (cecal stasis), but in which, nevertheless, marked puddling in the caput coli is distinct.

We desire concretely to draw attention to a form of stasis existent mainly in the caput coli, not because in the study of the cases an entity of importance can be attached to it, but because it does not always exist with so-called cecal stasis, may occur when the rest of the right colon drains practically well enough, and clinically it appears to be of more than casual roentgenological interest in symptomatic ways, although the symptoms cannot be sharply differentiated from colonic stasis in a general way.

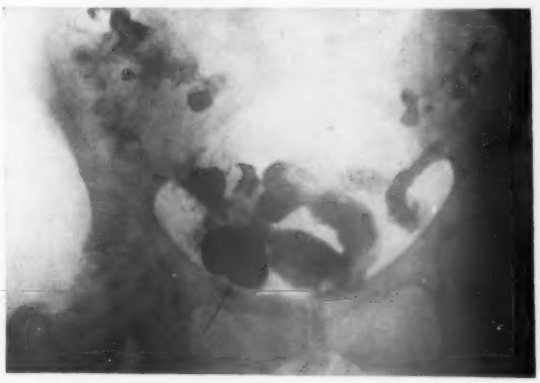

FIG. 3. The cecum may be displaced downward well over the pelvic brim with torsion of the caput from weight of the barium. This is shown with general stasis in the colon, but puddling in the caput is distinctive.

FIG. 4. Another case in which a clysma had been given. It will be noted here that the transverse and right colon contain bismuth from the clysma, but the puddling of the barium of the day before is plainly visible (arrow pointing).

* BEHAN. Cecal stasis and its relationship to appendicitis. *Penn. M. J.*, Dec., 1920.

The easiest way to observe the condition is to follow the method employed at the Mayo clinic of having the patient take barium six hours before the first roentgen-ray observation, the second dose being given at that time. On the next day (thirty hours after the first dose and twenty-four hours after the second) the caput coli is observed before a clysma is given for colon study.

The suggestion is marked that this puddling occurs in the caput below the level of the ileocecal valve, and it is this limited residue collection with practically an empty colon distal to the valve that is the distinctive feature of the roentgenological diagnoses, which is the only way we know of to diagnose it accurately.

In the study of the histories of a number of such cases there are no distinctive features leading to a definite diagnosis of caput puddling. Chronic colitis is more frequent and a history of chronic digestive disturbances with its many and manifold symptoms with general body results, occurs most often. Not uncommonly there is tenderness on direct pressure over the caput with a diagnosis of chronic appendicitis having been made, sometimes with a normal appendix present, although logically it could easily become diseased from the condition, and often is. When there is no ptosis of the caput cecum and this in the erect posture is situated above the brim of the pelvis, it is our belief that the condition is significant of adventitious or embryonic bands and veils covering the lower cecum. An abnormally large cecum does not seem to give this finding, but a marked Jackson or Jonnesco membrane commonly does. On occasions, adhesions from the appendix attached to the cecum have produced the finding. In the vast majority of our cases embryonic bands and veils with thickened edges and abnormal anchorage of this section of the gut are no doubt the cause of this roentgen-ray finding.

CASE OF KÖHLER'S DISEASE

BY BENJAMIN M. BERNSTEIN, M.D.

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IN 1908, Köhler of Wiesbaden first described a condition affecting particularly the scaphoid bone of the feet. He also stated that there may be a coincident affection of the patella on the same side. Since then several other observers, amongst whom may be mentioned Fassett, Pfahler, McClure and others, have reported similar cases. Practically all the cases so reported, with the single exception of those in Köhler's original article, mentioned the scaphoid bone as the only one involved, leading to the condition being sometimes known as "isolated disease of the scaphoid." In view of the original description by Köhler and the findings of the case which I am here reporting, the latter designation of the disease is not quite applicable. It seems to me that we shall be obliged to adhere strictly, at least for the present, to the name "Köhler's Disease." Further findings in regard to the etiology and pathology of the condition may cause us to change our views relative to the name at some future date.

CASE 1. Child, male, approximately five years of age; normal as for general inspection; no previous or family history of any consequence. Child complained of indefinite pains; sometimes in one leg, sometimes in the other, at irregular intervals, with no localization at any particular time. On examination, he had a mitral lesion; had no outward signs, swellings, or other marks which might lead one to a possible diagnosis of any disease affecting either leg. Due to the suspicion of possible tuberculous disease in the knees or hips, I

was requested to radiograph him from hip-joint to foot. I found the following: neither hip-joint showed evidence of disease; the right patella seemed rudimentary in size and form, being about one-fourth the size of the left. Both scaphoids were much smaller than they should have been at his age in comparison with the growth of the other tarsal bones. In addition, the right scaphoid showed a very definite hypercalcification. The remaining bones of both feet were of normal appearance, contour and calcium content.

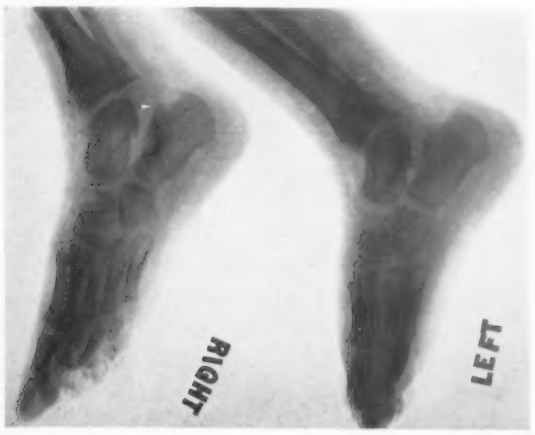

FIG. 1. Lateral view, both feet. Note hypercalcification of right scaphoid.

FIG. 2. Dorso-Plantar view, both feet.

I might also mention the fact that the child had a bilateral second degree flat foot.

Going into this child's history very thoroughly and carefully, I was unable to elicit that there had been any trauma, either direct or indirect. There was no tuberculosis or syphilis in the family. The child's brother was perfectly normal and healthy.

In Pfahler's report, he mentions the fact that one of his cases had a cardiac lesion, as has this child. He gives it as his opinion that the condition is an osteitis

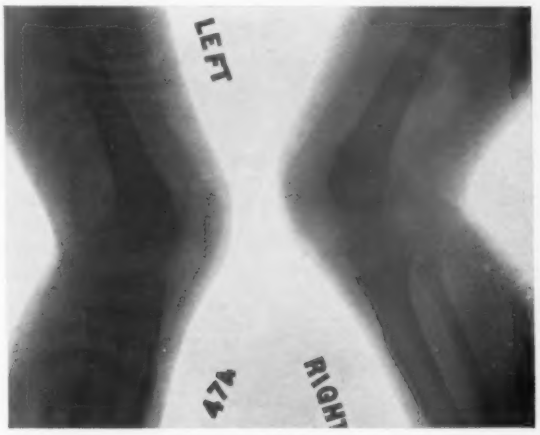

FIG. 3. Lateral view, both knees. Note rudimentary right patella.

of traumatic or rheumatic origin. In my case, trauma can quite definitely be ruled out, as it has also been by various other observers who have reported similar cases. It seems to me that in view of the indefinite unlocalized pains, and the coincident cardiac lesion in Pfahler's, as in my case, the theory of a rheumatic etiology may well be kept in the foreground.

Although the condition is a self-limited one, tending to spontaneous recovery, rest and massage with the possible administration of calcium, phosphates, and thyroid may be used as therapeutic measures. The condition is interesting because of its unusual character and manifestations, its inability of diagnosis by clinical means and its medico-legal importance in cases of injury to the foot or knee.

In conclusion, I wish to state that I have recently re-examined this child after a lapse of about six months and have found a tremendous improvement, particularly in the scaphoid, without definite therapeutic measures having been undertaken in its cure.

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THE AMERICAN JOURNAL OF ROENTGENOLOGY
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Information of interest to all readers and lists of officers of The American Roentgen Ray Society and The American Radium Society will be found on the two pages preceding Table of Contents.

TWENTY-THIRD ANNUAL MEETING THE AMERICAN ROENTGEN RAY SOCIETY
LOS ANGELES, CAL., SEPTEMBER 12, 13, 14, 15, 16, 1922
Headquarters, Meetings and Exhibits: Hotel Ambassador, Los Angeles, Cal.

PROFESSOR JOHN SANDFORD SHEARER: AN APPRECIATION

THE death, on May 17, 1922, of Dr. John Sandford Shearer, Professor of Physics at Cornell University, removed from the world of science one who had gained an enviable and a well-deserved reputation, both here and abroad, by his unique work in that very important borderland between physics and medicine. His work in roentgenology, to which he devoted the last decade and a half of his life, I shall leave to others to describe. But I deem it an honor and a duty, sad though it be, to accept the invitation of the editor of this Journal, to write of the work of my friend and colleague in his connection with the Physics Department of Cornell.

Professor Shearer was born in New York City on October 20, 1865. His early years were spent in Homer, N. Y., where he taught in the Homer Academy before his entrance into Cornell University in September, 1889. He completed the four-year course leading to the degree of B. S. which degree he received in June, 1893. The degree of Ph. D. was conferred on him in 1901.

During his undergraduate work his proficiency in physics was such that, upon graduation, he was appointed assistant in the Physics Department. After one year he was promoted to an instructorship. In 1903 he was made assistant professor, and in 1910 was promoted to a professorship, which appointment he held until the time of his death. With the exception of a half-year on Sabbatic leave spent at Columbia, and something over two years in the Sanitary Corps of the U. S. Army, during the late war, first as Major and later as Lieutenant Colonel, he spent his entire career at Cornell University.

He is survived by three sons: Lee, of Argentina, South America, and Howard and Harold of Ithaca, N. Y. Mrs. Shearer, née Minnie Lee of Cuyler, N. Y., to whom he was married in 1888, died in January last, after an extended illness. The death of his wife was a blow from which he did not recover, and which, without doubt, made him less able to bear the operation that resulted in his death.

Professor Shearer's activities at Cornell naturally fall into three groups: Teaching, research and other scientific work, and administration.

His activities as teacher covered almost the entire work of the Physics Department. Shortly after his appointment as instructor, he was placed in charge of a large undergraduate laboratory course in General Physics given primarily to engineering students. Soon, however, the growth of the department demanded an additional lecturer in the elementary course. Shearer was the logical choice. To this work he devoted a very large amount of time and thought. He was particularly skilful as a demonstrator, and it is, without

doubt, due to this long experience in lecturing that he acquired an unusual facility of expression and of explanation which later he used to such good advantage in presenting fundamental principles of physics to roentgenologists and to the medical profession in general.

His later work among undergraduates consisted in organizing and in giving courses in *x*-rays and general roentgenology, particularly to pre-medical students.

Among the courses, primarily for graduate students, which he offered, may be mentioned those on Geometrical and Physical Optics, and on Heat and Thermodynamics. These later gave way to advanced courses on *X*-rays and Radioactivity. He also directed a large amount of graduate research, particularly in low temperature work and later in *x*-rays.

The wide range of Professor Shearer's scientific work may be judged by the following partial list of papers:

Vibration of Tuning Forks (1893)
Behavior of Dielectrics when Subjected to High Potentials (1902)
The Heat of Vaporization of Air (1902)
Bibliography of Low Temperature Work (1902)
The Heat of Vaporization of Nitrogen (1902)
Heat of Vaporization of Oxygen, Nitrogen and Air (1903)
Coefficient of Expansion at Low Temperatures (1905)
Specific Heat of Air at Low Temperatures (1905)
The Thermal E.M.F. of the Nernst Filament (1912)
Factors Governing the Photographic Action of Roentgen Rays (1915)
Losses in High Tension Transmission (1915)
The Physical Aspect of Roentgen-Ray Measurement and Dosage (1916)
U. S. Army *X*-Ray Manual (1918)
The Physics of the Roentgen Ray (1920)
Le Tube Coolidge en Radiographie et en Radioscopie (1920)
X-Ray Dangers (1920)
X-Ray Dosage (1921)

During the decade 1905 to 1915, Professor Shearer carried a very heavy load of administrative and kindred work. It always happens, in a university, that a man who proves himself a capable organizer, a good committee worker, and a good administrator, is overloaded with such work, regardless of his value as a teacher or productive scholar. Not only was Professor Shearer very effective as a member of numerous committees of the University, of many of which he was chairman, but his advice and counsel were frequently sought in connection with the larger projects of the University, particularly where installations of new apparatus and equipment were involved. For example, in the Physics Department he planned and supervised the installation of the low-temperature equipment, and of the high-pressure storage tanks for oxygen and hydrogen. He was instrumental in perfecting and, for a long time, in supervising, the instrument shop. The entire list of appliances and conveniences which are directly due to his planning and good judgment would be a very long one.

Whatever his work, whether teaching, research, or administration, he always kept clearly in mind that one must give most careful consideration to that plan or procedure which is most expedient. In teaching, he emphasized, but not too strongly, the applications of the principles under discussion. In research, both his own and that of graduate students, he was constantly looking for the simplest, most direct method. In his work of administration he tried to evolve that plan or lay-out which would result in the greatest utility and convenience.

It was this practical turn of mind which, quite by accident, was responsible for his interest in *x*-rays. An *x*-ray outfit was suddenly and urgently needed at the University Infirmary for diagnosis of a very serious case. As no outfit then in use in Ithaca was adequate, it was decided to get one, with all possible speed. Accordingly, Professor Shearer, because of his proven ability in emergencies of this kind, was commissioned to go to New York, select an outfit, bring it back to Ithaca, and set it up for operation. He was so successful in this mission that he was given permanent charge of the outfit. And it was

from this small beginning that his interest in *x*-rays grew.

He very early saw the importance of coordinating the physical principles of *x*-rays with medical practice. But he realized that if one were to enter this middle ground between physics and medicine, one must have a sufficient knowledge of the latter to get the medical point of view. Accordingly, he devoted himself to a study of anatomy and medical practice generally, so as to be able to advise with medical authorities on problems of roentgenology. One need only point to his international reputation, his war medals from the French Government, and the general esteem and respect in which he was held by the roentgenologists of the country, to appreciate the success which he made of this work, to which he gave the last and the best years of his life.

Not only have his associates lost a trusted friend and a respected colleague, and the world of science, both in physics and medicine, a tireless worker, but his death cuts off the development of many plans and projects which he had in mind, which, when completed, would have been of permanent value to applied science.

Few men have had the courage, in these days when each science is a small universe unto itself, to take up the much neglected, but highly important, middle ground work, such as is found between physics and medicine. Professor Shearer's place among his fellowmen would have been assured, had he done nothing more than point out, as by actual work he did point out, the importance of this general field, and what could be accomplished by work therein.

The following concluding paragraph extracted from the resolutions adopted by the faculty of Cornell University in appreciation of their late colleague sums up the feeling of respect in which Professor Shearer was held by the University community:

"There is reason to believe that Professor Shearer's early death was due to his exertions in war service, and that he is to be counted among those who gave their lives for the country. In him this faculty has lost a valued colleague, the community a public-spirited citizen and the sciences of physics and radiology a worker of eminence and renown."

F. K. Richtmyer,
Cornell University,
Ithaca, N. Y.

PROFESSOR JOHN S. SHEARER

He was to us a friend, a companion, a wise counselor. He was to the world a zealous, consistent, effective worker in humanity's cause.

His contribution to roentgenology was very great. It was creative, inspirational and educational. His interest in the subject was intense, and his zeal never flagging. He brought to his work in this field a firm grasp of essentials, and an eye which was always fixed on the goal. There are few, if any, who combine his understanding of the underlying physical principles with his knowledge of the art of roentgenology. In this respect, he occupied a unique position among us.

A task that he once set his hand to, he finished, and his high ideals and thoroughness show in everything that he undertook. They are seen in the development of the *x*-ray apparatus which was so useful to the United States Army during the Great War, and in the subsequent redesign of such apparatus, incorporating the lessons learned during active war service. The same painstaking care is seen in his still later work on an apparatus for high voltage deep therapy, which he carried out as consultant to the General Memorial Hospital of New York.

His unusual conscientiousness was shown by his work as Chairman of the Safety Committee of the Society. In this connection, he was not content with the formulation of recommendations based upon his rich past experience, but must first investigate as thoroughly as possible all reported accidents and must then try quantitative experiments to determine the exact degree of safety afforded by various schemes.

Although he had strong convictions, his attitude was invariably truly scientific. He was always willing and anxious to review a situation upon the appearance of new evidence.

His mind was exceptionally well balanced. He was progressive, in the sense that

by reading and by experiment he kept abreast of scientific progress in his chosen field and was always eager to apply new knowledge to useful ends. He was, at the same time, helpfully conservative, giving frequent timely warnings against the blind following of fads and fancies, and, at the same time, pointing to other paths leading upward and onward over firm ground.

To know him was to appreciate him, and it was, therefore, only natural that roentgenologists and other members of the medical profession should individually and collectively turn to him for advice and make heavy demands upon his time and energy. He gave as freely as they asked. He was never satisfied with the selfish pleasure of knowing something, but was always eager to pass his knowledge on to others.

He was an unusually effective teacher, marshalling his facts in logical order, making his points clear by homely pertinent illustrations, and leavening the whole with a rich vein of humor.

It is hard for those familiar with the extent of his labors in roentgenology to realize that, in addition to this, he was an active teacher of general physics as well.

Through the indelible impression which he made upon the science and art of roentgenology, he will always be with us.

May his memory serve as an inspiration to others to try and devote themselves as faithfully, as unselfishly and as helpfully to the service of mankind.

May 31, 1922.

W. D. Coolidge, Ph. D.,
Research Laboratory,
General Electric Co.,
Schenectady, N. Y.

PROFESSOR SHEARER'S SERVICES TO THE ARMY

Professor Shearer was among the earliest to volunteer his services to the Medical Department of the Army at our entrance into the World War, although he was at that time long past the age when such a course would be expected.

He secured leave of absence from Cornell University, and even before he was commissioned in the Army he began instruction work in the Army School for Instruction of Roentgenologists in New York City.

He was later commissioned as Major, and continued his work in the school until the spring of 1918. During this time he organized a course for the thorough instruction of roentgenologists in the technique of roentgenology as applied to military medicine and surgery.

The work of Professor Shearer during the first year of the war contributed more than can be calculated to the success of the *x*-ray work among the sick and wounded in the American Army. He so organized the course of instruction as to make it possible to give physicians with little or no previous training a practical working knowledge of *x*-ray technique, in a comparatively short time. At the same time that he was engaged in this instruction work, he devised various types of apparatus subsequently used in our army. Among these was the Army Bedside Unit, which proved of such immense value in every type of military hospital. In addition to all this, his energy and enthusiasm enabled him to act as the constant advisor in all technical matters of the *X*-Ray Division in the Surgeon-General's Office.

When, in the spring of 1918, he was asked if he would be willing to go to France to remain as long as his services were necessary, he replied within the hour in the affirmative.

Arriving in France, he went to work with characteristic energy to assist the Red Cross in its *x*-ray and electrical problems, and soon after, was again at work for the Medical Department of the Army, establishing a general repair shop for *x*-ray apparatus in Paris. From then until the end of the war, and for eight months after its close, he remained on duty in France, supervising the repair of apparatus, and the modification of machines to suit the various types of electrical current encountered in different parts of the country, and finally making settlement with French manufacturers and the French Government for apparatus purchased from them in the early days of our activities in the war.

He returned to this country in the summer of 1919, having been promoted to the grade of Lieutenant Colonel upon special

recommendation of the Chief Surgeon of the American Expeditionary Forces. The stress of his work in France had greatly impaired his health, and he never recovered his former strength and energy. In spite of this, upon the request of the Surgeon-General, he undertook to devise an Army portable apparatus based upon the experience of the World War. After more than a year of exacting work he finished this task, and produced a complete *x*-ray apparatus which was immediately adopted by the Medical Department of the Army. This apparatus was, in most essential particulars, that devised and used by our Army during the war, but it contained numerous modifications and improvements that render it much more durable, more highly efficient, and more readily portable than any *x*-ray apparatus ever before constructed for military service.

If Professor Shearer had done nothing in all his life except what he accomplished during the world war, the entire nation would owe him an eternal debt. He gave without stint or thought of reward out of his great fund of experience and knowledge.

Today those who came in close contact with him during the war not only mourn the loss of a friend, but wish to offer this little tribute of words, however inadequate, to a man whose well-poised judgment and ripe experience carried them safely through many trying experiences, and contributed incalculably to the success of the *x*-ray work in the American Army.

ARTHUR C. CHRISTIE, M.D.,
1621 Connecticut Ave., N.W.,
Washington, D. C.

CORRESPONDENCE

To the Editor:

On page 113 of the February issue of the JOURNAL OF ROENTGENOLOGY Dr. Levin is quoted as stating that he uses a 9 in. gap, 7 ma., 8 in. distance, time forty-five minutes, no filter, in the treatment of frogs, to determine the blood changes.

In replying to my letter of inquiry to him he states that he actually gives this treatment, and that the frogs recover in four days. The last sentence of his letter, however, states that he is using German induction coil.

I wonder if you do not see the necessity of calling attention in an editorial to the desirability of having experimenters make accurate statements with reference to technique. The facts are, of course, that Dr. Levin is not using more than a 5 in. gap, and probably not more than 4½ in.; and it is apparent to anyone that the dosages indicated in this article would kill any frog or anything else.

The vital point of this communication is that inasmuch as he has fallen down in the matter of *x*-ray dosage, or rather has failed to give a technique which is in common use, the whole experiment is well-nigh worthless.

This error is not an uncommon one, and it seems to me highly important that any statement with reference to *x*-ray technique should be so accurate and so carefully done that it could be duplicated anywhere in the world by any other investigator.

Very truly yours,
E. A. MERRITT.

Washington, D. C., April 13, 1922.

To the Editor:

In his letter to you, dated April 13th last, Dr. E. A. Merritt makes a statement that what I consider to be a 9 in. gap is in reality only a 5 or 4½ in. gap. The reason for his assertion is apparently the fact that I use an induction coil instead of a step-up transformer.

Dr. Merritt seemingly is not familiar with the construction of the therapeutic coils used in Germany and England. The inverse current is reduced in them to a very small fraction, and the length of the parallel spark gap indicates at least as many kilovolts on the secondary as in a transformer. Furthermore the secondary voltage on the coil is constantly controlled by Bauer's Qualimeter, which acts very well up to a 10 in. spark gap. In accordance with Merritt's notions, the latest model of a therapeutic coil, the "Symmetrie" machine which delivers a 20 in. (50 cm.) spark gap, really gives only a 10 in. gap, or, in other words, does not give *x*-rays of any shorter wavelength than an old Snook machine. When Dr. Merritt talks of a "technique which is in common use," he does not seem to realize that on the continent of Europe and in England, for *x*-ray therapy, 10 induction coils are being used as against 1 transformer.

I fully agree with Dr. R. Knox and the majority of German clinicians, that even with a Coolidge tube the coil is superior to a transformer for therapy. My latest high voltage installation is, nevertheless, a transformer; but the reason for it is the lack of repair stations in this country for induction coils.

Now as regards the sentence in Dr. Merritt's letter, "The whole experiment is well-nigh worthless." As I have shown above, his premises are wrong. There is, however, a more

important matter connected with it. In my thirty odd years of experimental work in medicine, I have never attempted to condemn another worker's results without first repeating his experiments. Roentgenologists must learn to use similar scientific methods in radiobiology and radiotherapeutics, and not use loose methods of disparaging criticisms.

Very sincerely yours,

I. LEVIN.

New York, May 27, 1922.

DR. EDWIN R. RASELY

We regret to announce the death of Dr. Edwin R. Rasely, which occurred at his home in Uniontown, Pa., on Wednesday, July 12th. His death was due to accidental electrocution. He was developing kodak films in his dark-room when the accident occurred. It is believed that he touched a wire with his arm, making a short circuit with the metallic sink, as evidenced by a burn at the point of contact. Dr. Rasely was one of the earlier workers in roentgenology, and was favorably known by a large cortege of friends throughout the country. His reputation in the community in which he served was not only that of a roentgenologist, but also that of a public-spirited citizen.

THE PHILADELPHIA ROENTGEN RAY SOCIETY

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PACIFIC SECTION OF THE AMERICAN ROENTGEN RAY SOCIETY

At the spring meeting of the Pacific Section of The American Roentgen Ray Society, held May 18th in Yosemite National Park, the following were elected to office for the coming year:

President: M. P. Burnham, San Francisco, Calif., Vice-President: F. C. Swearingen, Pomona, Calif., Secretary: Roy A. Payne, Portland, Ore.

A CORRECTION

In the article by Frank Rieber on Standardization of the Measurement of Tube Potential, published in the June, 1922, issue of the Journal, Mr. Reiber is announced to have read his paper in January, 1922. This date should have been January, 1921.

THE LEONARD PRIZE

The American Roentgen Ray Society is again offering the Leonard Prize in 1923, details for which appear on advertising page viii of this number of the Journal. The manuscripts submitted for the 1921 prize were of a high order of merit and covered a variety of subjects pertinent to Roentgenology. It is to be hoped that the contestants for the next prize will be equally zealous in their efforts.

Subscribers to THE AMERICAN JOURNAL OF ROENTGENOLOGY *visiting New York City, are invited to make the office of* THE JOURNAL (*69 East 59th Street, New York*) *their headquarters. Mail, packages or baggage may be addressed in our care. Hotel reservations will gladly be made for those advising us in advance; in this case, kindly notify us in detail as to requirements and prices. List of operations in New York hospitals on file in our office daily.*

TRANSLATIONS & ABSTRACTS

PINCH, A. E. HAYWARD. Annual Report London Radium Institute. (*J. Am. M. Assn.*, April 1, 1922, lxxviii, No. 13, 985.)

In the annual report of the Radium Institute, the medical superintendent, Mr. A. E. Hayward Pinch, reviews the work done since its foundation, which covers a period of rather more than ten years. He is thus able to furnish an estimate of the therapeutic value of radium based on wide experience. During the period, 7,750 patients have been dealt with and nearly 100,000 treatments administered. He divides the cases into four classes: (1) Those in which cure, either complete in the case of the non-malignant, or apparent in the case of malignant disease, may be confidently expected. This class includes chronic eczema, seborrheic eczema, lichenification, cavernous nevi, keloids, papillomas, keratomas, corns, rodent ulcer, lymphosarcoma, and sarcoma of the naso-pharynx. (2) Those in which great benefit may be expected: psoriasis, xanthelasma, xeroderma pigmentosum, Fordyce's disease, leukoplakia, capillary nevi, spring catarrh, lupus erythematosus and vulgaris, tuberculosis adenitis, vicious cicatrices, Dupuytren's contraction (early), exophthalmic goiter, parenthymatous goiter, splenic and lymphatic leukocythemia, lymphadenoma, mediastinal tumors, epithelioma of the skin, cornea, vagina and urethra (female), carcinoma of the breast, uterus, bladder, prostate and thyroid, sarcoma (excluding endosteal), endothelioma, angioneurotic edema, and arthritis deformans (early infective cases). (3) Those in which the result is doubtful, some cases responding very well while similar ones fail to show any improvement: Pruritus, neuralgia, neuritis, epithelioma of tongue, mouth, fauces, larynx and esophagus, carcinoma of the stomach, intestine and rectum, myeloma, melanoma and glycosuria. (4) Those in which radium is practically useless: Dupuytren's contraction (late), kraurosis vulvæ, adenomatous goiter, osteitis deformans, acromegaly, cysts, lipomas, enchondromas, osteomas, endosteal sarcomas, syphilis, locomotor ataxia, disseminated sclerosis, pyomyelitis and paralysis agitans.

By far the greater number of patients applying to the Radium Institute suffer from malignant disease, which usually is advanced and inoperable or has recurred after operation with no possibility of further surgical interference. To use the term "cure" when discussing the radium treatment of such cases would be unwarrantable; but results have been obtained in the arrest of the progress of the disease which improve the general health and comfort to a degree that cannot be excelled, and is rarely equaled, by any known medical or surgical measures. At present the institute has records of many patients suffering from recurrent inoperable malignant disease, who first presented themselves for treatment seven or ten years ago, and who now lead useful, comparatively healthy lives, the disease having been rendered quiescent by the treatment.

With increasing experience it has been possible to augment the dosage greatly. In the early days of the institute, a dose of 3,000 mg. hours was considered large; now it is common to give from 20,000 to 30,000 mg. hours, and, if judiciously administered, this entails little systemic disturbance. Considerable advances have been made in the treatment of such conditions as carcinoma of the prostate, bladder and uterus, mediastinal tumors, splenic and lymphatic leukocythemia, lymphadenoma and tuberculous adenitis. Results are now obtained far more striking than were at first anticipated. The chief problem to be solved is the treatment of deep-seated growths to which there is no adequate approach by the natural channels; but improvements in technique are being devised from time to time which are slowly but steadily lessening the difficulty. For widespread conditions, roentgen rays are considered preferable to radium, as in generalized psoriasis, the early stages of cancer encuirasse, generalized infection of the peritoneum, and cystic disease of the ovaries. For these conditions an enormous amount of radium, mounted on numerous applicators, would be necessary to irradiate the whole area, while it can be easily done with a roentgen-ray tube. On the other hand, to give an intense dose over a small area, as in rodent ulcer, small superficial epitheliomas or recurrent nodules after excision of the breast for carcinoma, radium should be used, as by means of emanation applicators a powerful dose may be given to a very small area. In certain situations, such as the cavity of the uterus, bladder, larynx, esophagus, stomach and rectum, it is almost impossible to give an adequate dose of roentgen rays, but radium can be effectively used. Though physicists consider the gamma rays of radium analogous to the hardest cathodal rays of a roentgen-ray tube, clinical experience tends to show that there must be some difference, as frequently cases of lichenification, rodent ulcer and lupus vulgaris do not respond to roentgen rays but yield promptly to radium.

James T. Case.